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CLIFDEW-GRID: Early Warning Grid-Based Risk Modelling of Climate Induced Forced Displacement

Climate and displacement workshop:
04 - 05 November 2025

Data Science Team
Statistics, Data Science, and Survey Section
Global Data Service

Background

Background: project overview

Aims and Goals

Aim

Risk index for forced displacement

- Subnational (grid cell) level
- Monthly frequency

Case area

East, Central, and West Africa

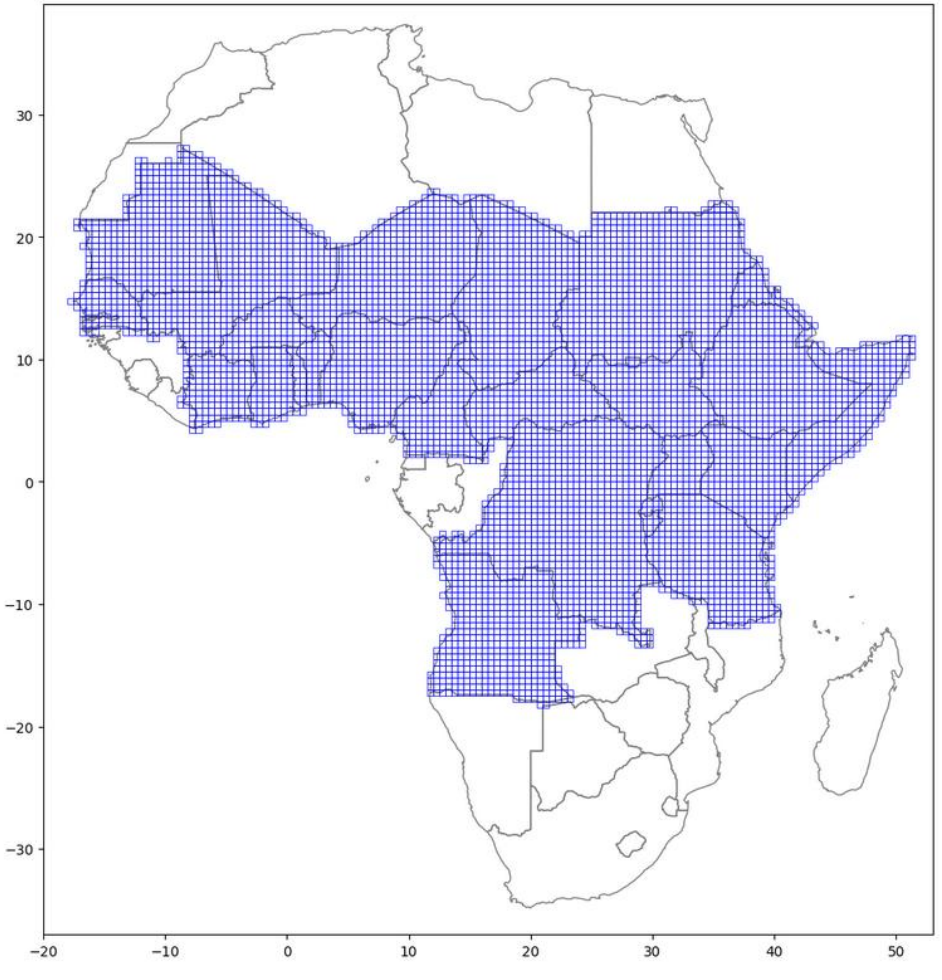
Goal

Early Warning Model and Insights

- Provide UNHCR and other humanitarian agencies and stakeholders with a tool for anticipatory action relating to forced displacement, taking climate change into account.
- Create deeper insights into the nexus between climate change and forced displacement.

Geographical focus

- East, Central and West Africa
- 0.5° grid-cells (approx. 55 km x 55km)
- Approx. 6220 grid-cells



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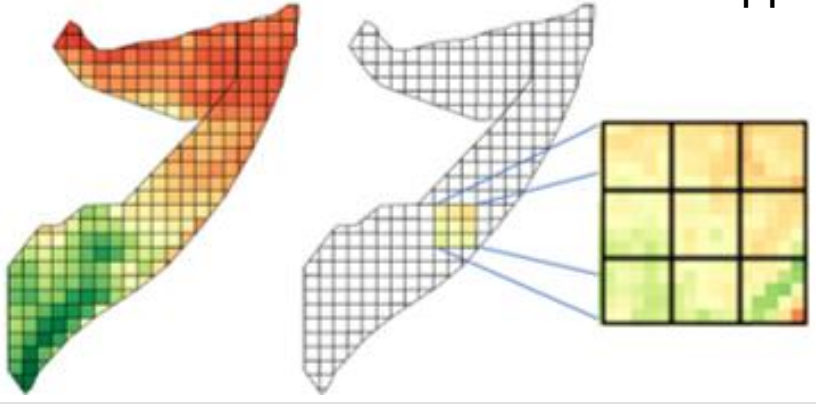
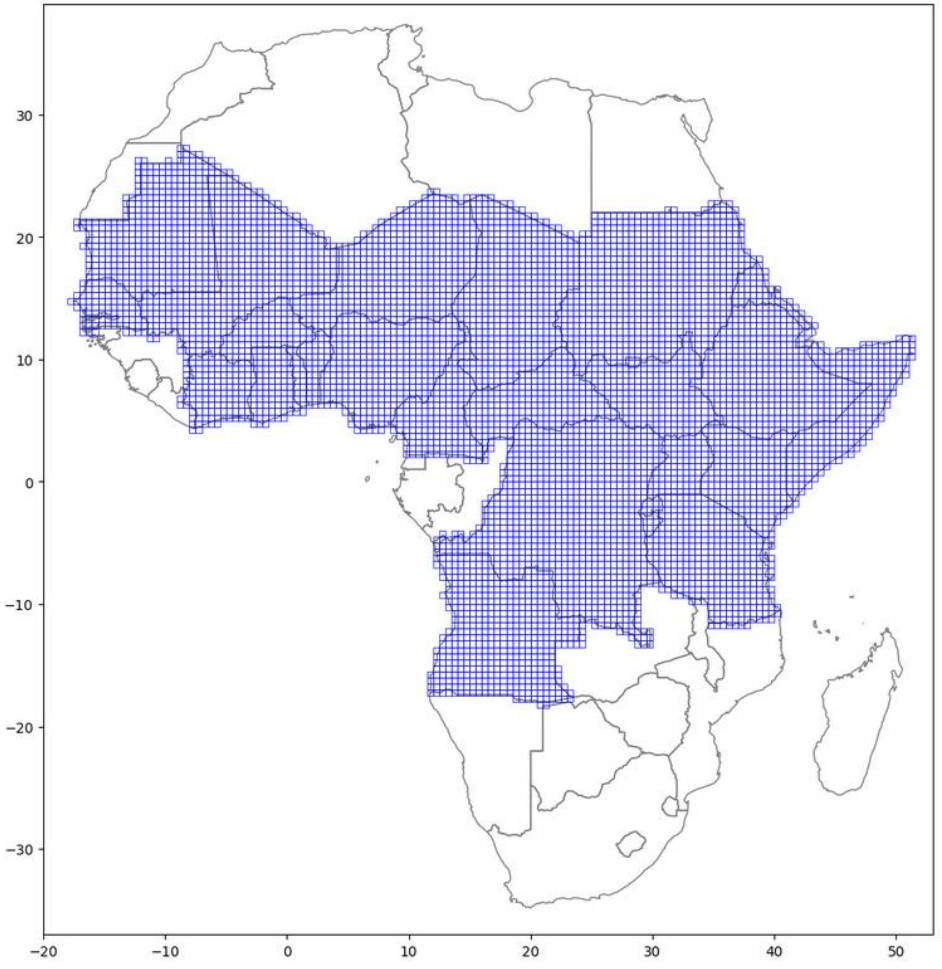
Geographical focus

- East, Central and West Africa
- 0.5° grid-cells (approx. 55 km x 55km)
- Approx. 6220 grid-cells

- Feature variable data collected at the 0.1° grid-cell level to account for variance
- Approx. 150,000 grid cells





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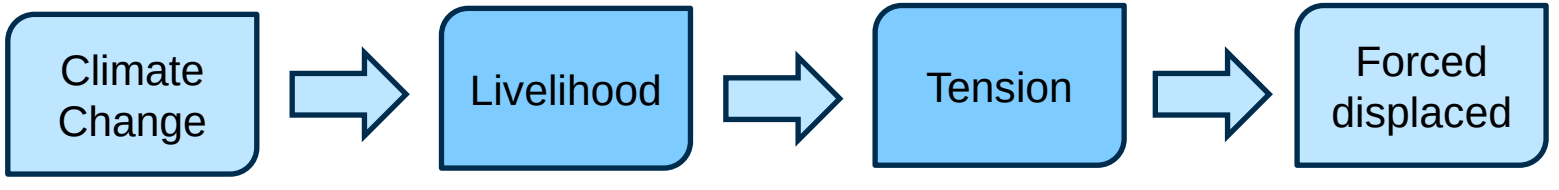
Project structure

Hypothesis

Modelling structure

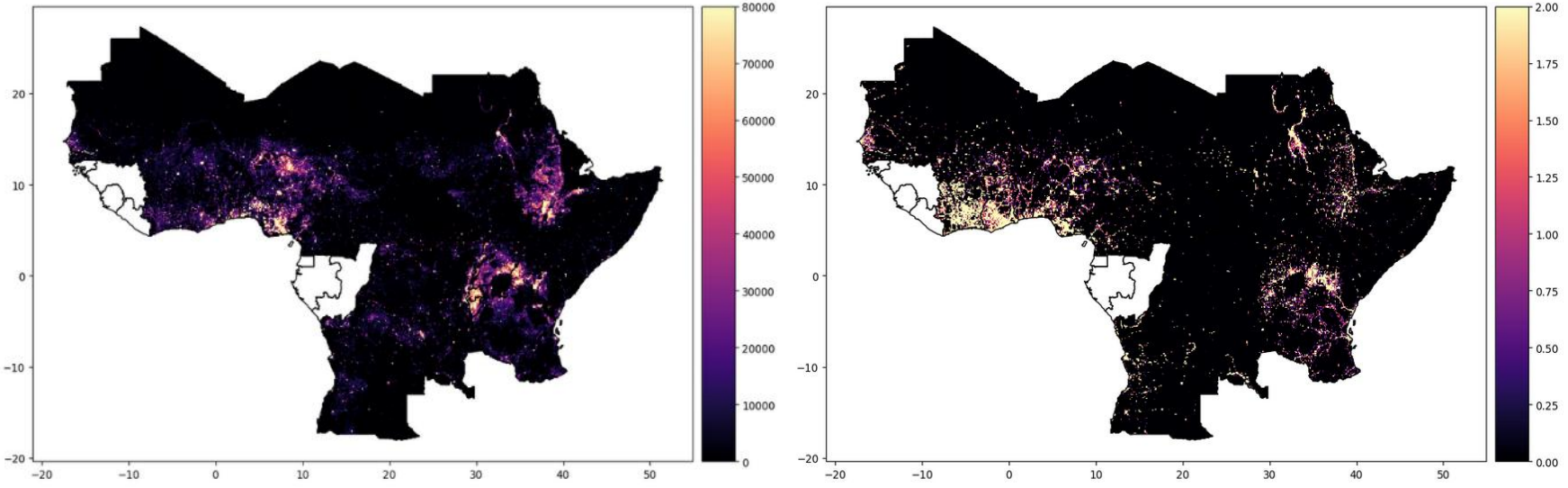
- Slow on-set climate change generates loss of livelihood.
- Loss of livelihood can lead to competition over diminishing resources, resulting in political tension.
- Conflict contributing to forced displacement.



Intermediate models

Monthly population

- LandScan population data
  - Annual frequency
  - 1000-meter resolution
- Based on sub-national information, observations are placed inside 0.1° grid-cells and aggregated to monthly time intervals using smoothing method
- Use monthly nightlight data (Defense Meteorological Satellite (DMSP) and Visible Infrared Imaging Radiometer Suite (VIIRS)) to correct monthly trends



Gridding LandScan population figures in year 2020 (left), gridded VIIRS nightlight radiance in May 2020 (right)

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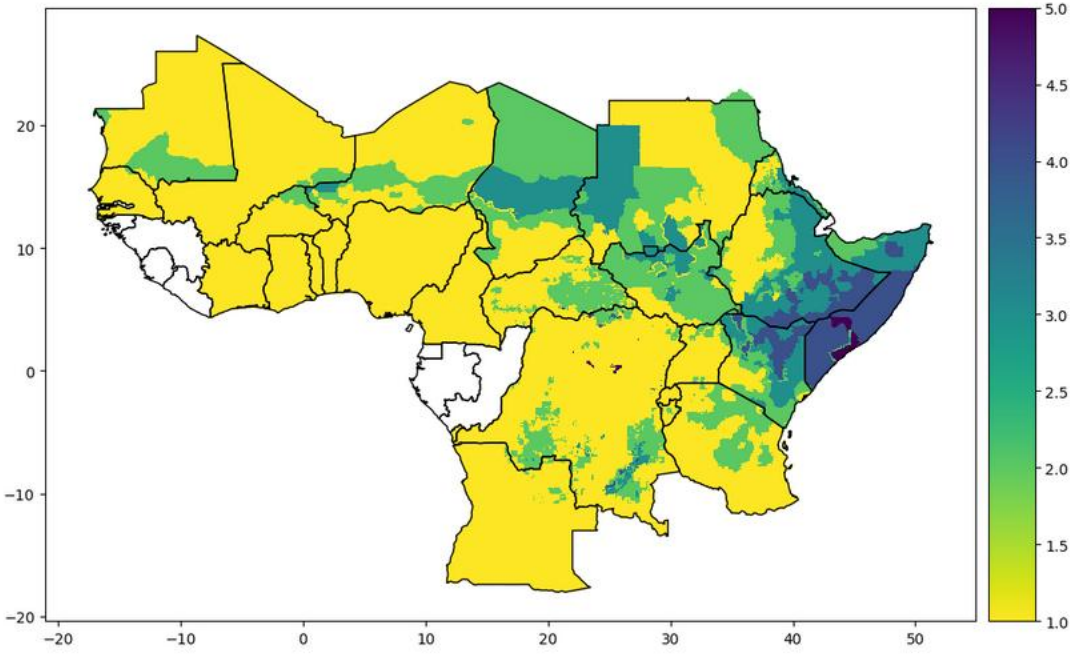
Monthly food security

- Famine Early Warning System Network (FEWS NET)
  - Food security evaluation within subnational geographical areas
  - Released every 3 months with current situation, 1 – 3 month prediction and 4 – 6 month prediction
- Backcasting model to predict monthly food security for time period before historical data is available
  - LightGBM with series of feature variables
- Apply forecasting model when waiting for new data to be released



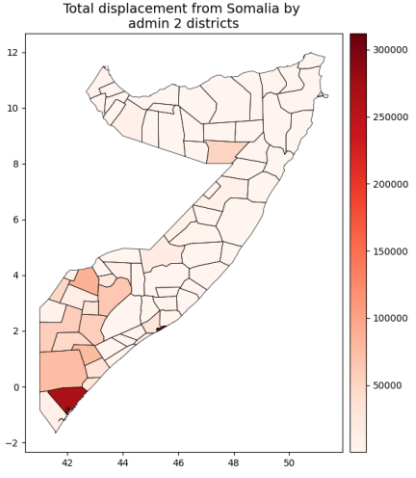
Gridded food security for July 2011

Gridding ProGres Displacement

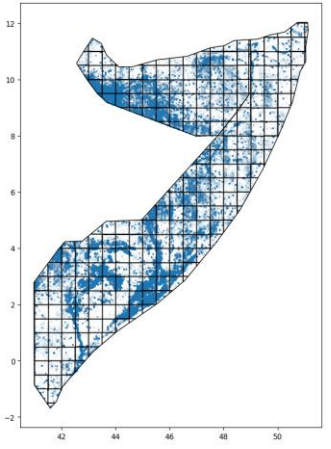
Success of the CLIFDEW project will hinge on UNHCR's ProGres data and especially placing observations within grid-cells

Need a method for placing observations into grid cells based on known subnational locations in data

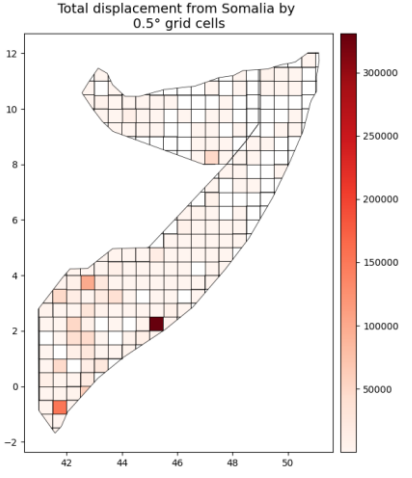
Predict grid-cell locations for observations using building prior key and other variables



ProGres data



Population distribution



Predicted grid cell displacement

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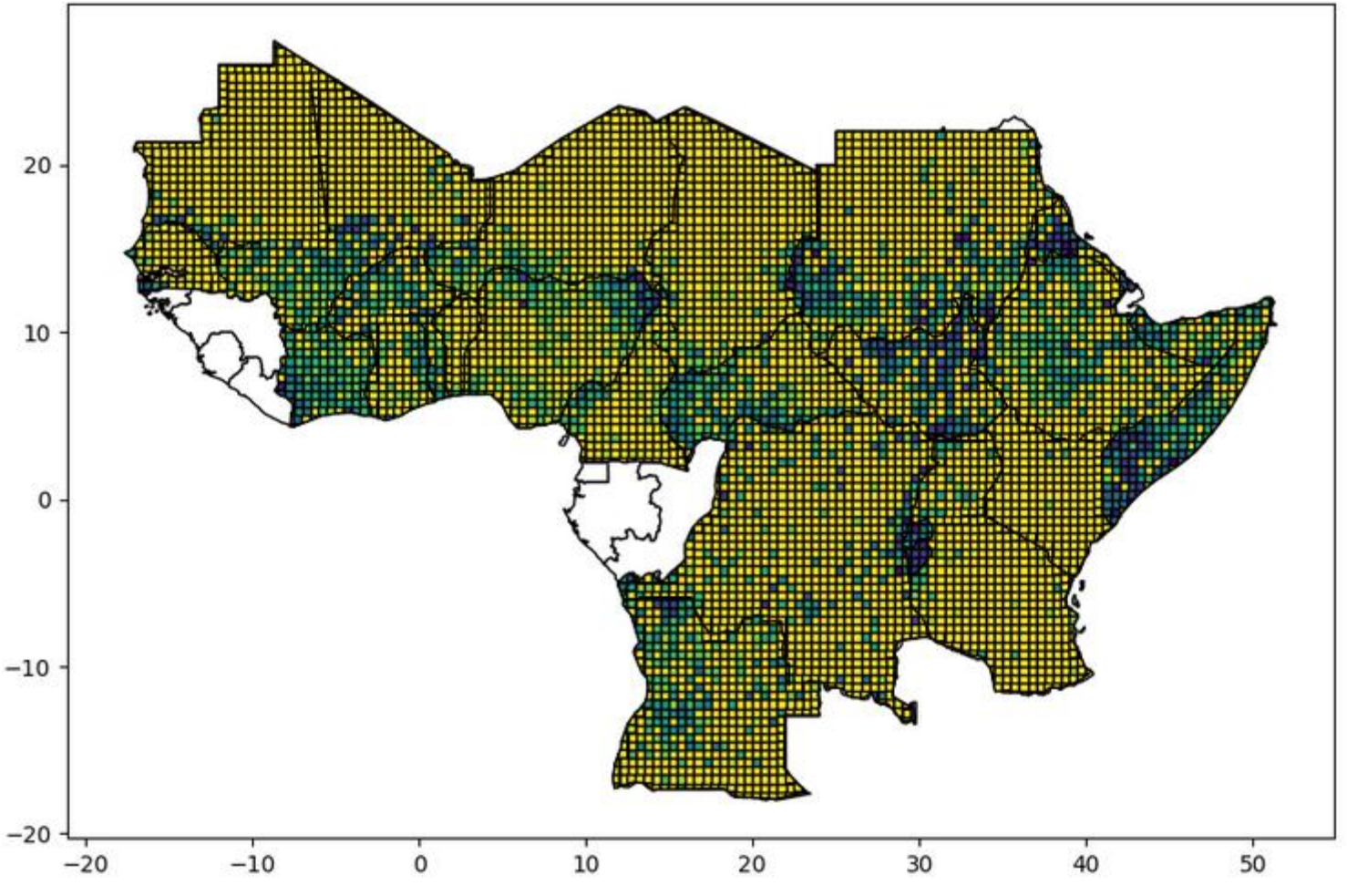
Gridding ProGres Displacement



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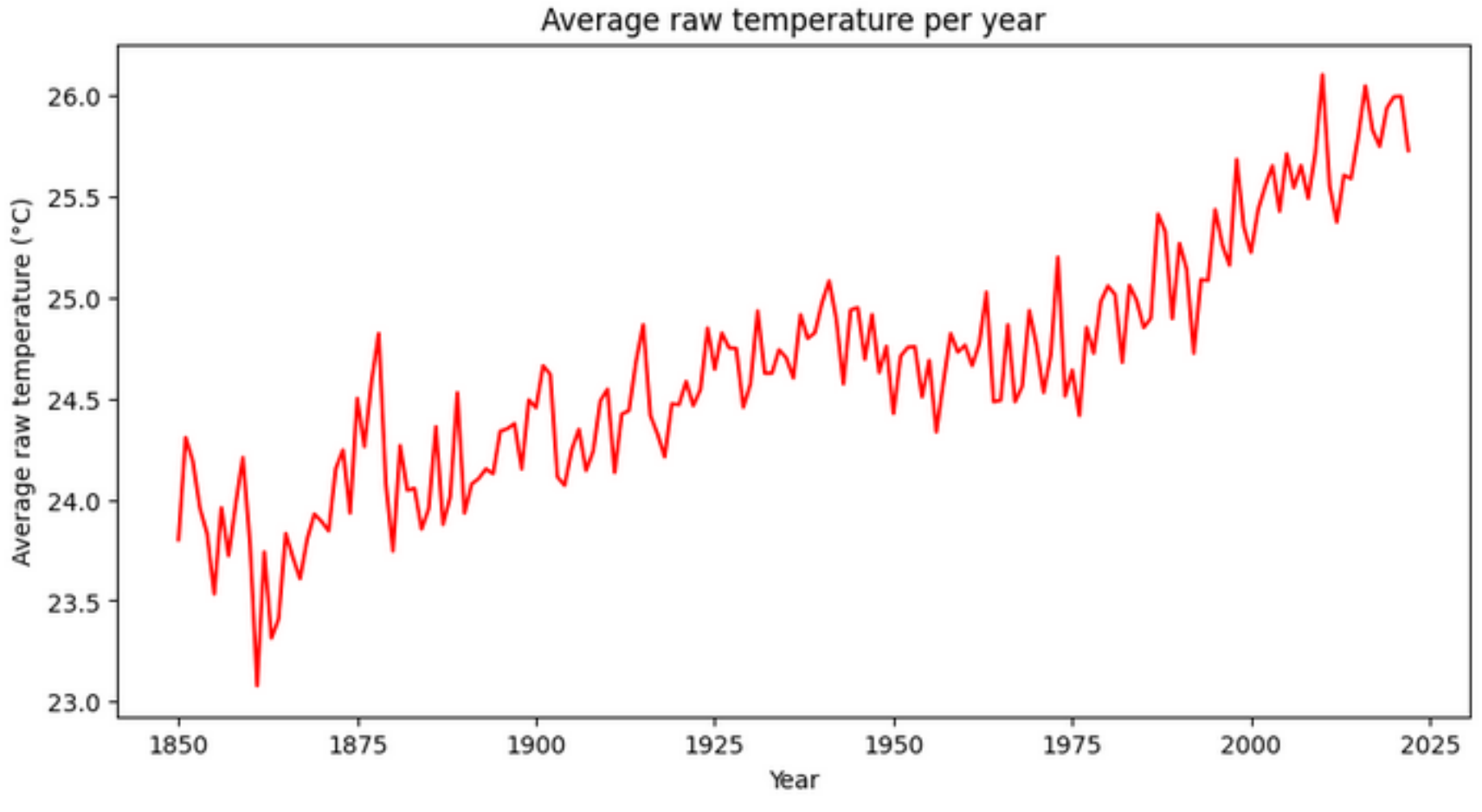
Feature variables

Variable	Unit	Source
Climate variables		
Temperature	Daily, 0.05° Daily, 0.10° Monthly, 0.25°	CHIRTS Copernicus ERA-5 Berkeley Earth
Precipitation	Daily, 0.05° Daily, 0.10°	CHIRPS Copernicus ERA-5
Normalized Difference Vegetation Index	Monthly, 0.05°	NASA
Standardized Precipitation Evapotranspiration Index	Monthly, 1.00°	SPEI Global Drought Monitor

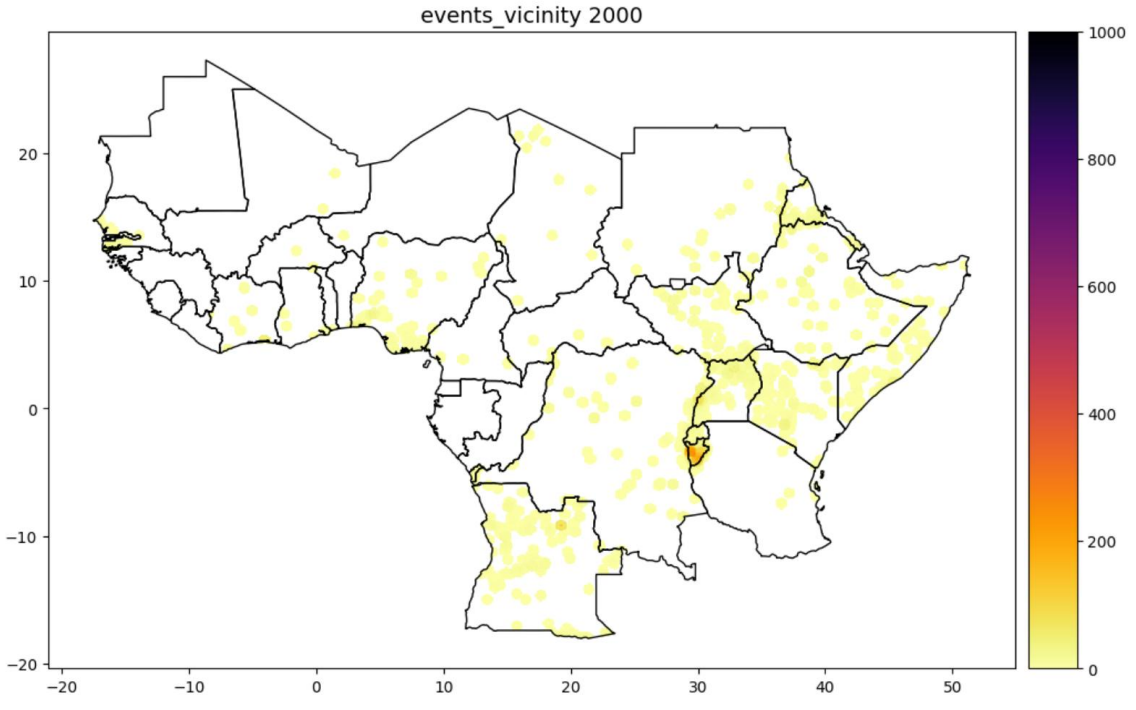
Resource and geographic variables		
Landcover	Stagnant, 0.05°	Copernicus
Agro-ecological zone	Stagnant, defined regions	International Food Policy Research Institute
Elevation	Stagnant, 0.10°	HarvestChoice CELL5M
River	Stagnant, defined regions	Natural Earth
Road	Stagnant, defined regions	Humanitarian OpenStreetMap
Market access	Stagnant, 0.10°	International Food Policy Research Institute
Subsistence Index	Stagnant, 0.10°	International Food Policy Research Institute, Harvard Dataverse

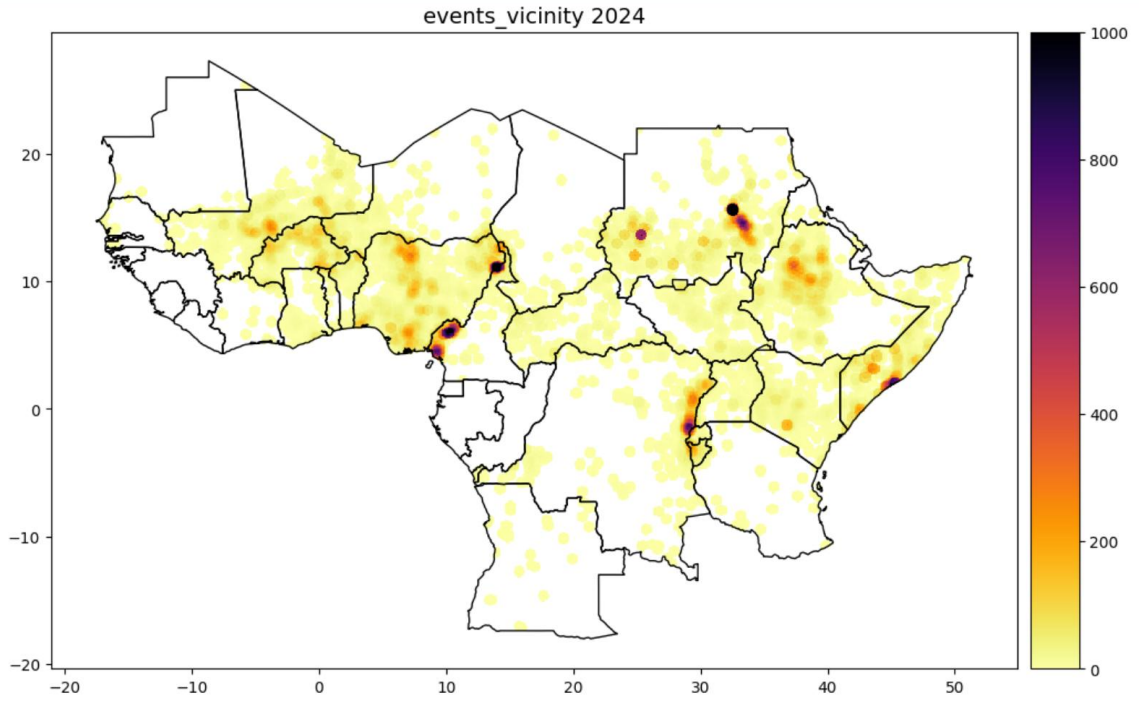
Demographic variables		
Population density	Monthly, 0.10°	LandScan, DMSP, VIIRS
Ethnicity	Stagnant, 0.10°	ETH Zurich
Food security		
Predicted food security	Monthly, 0.10°	FEWS NET
Socio-economic and wellbeing variables		
Child health	Monthly, 0.50°	PRIO
Gini	Monthly, 0.10°	WorldPop, VIIRS
Political variables		
Fragility	Annual, national	Fragile States Index
Conflict variables		
Conflict	Daily, geo-point locations	ACLED

Climate conditions: temperature over time



Tension: conflict





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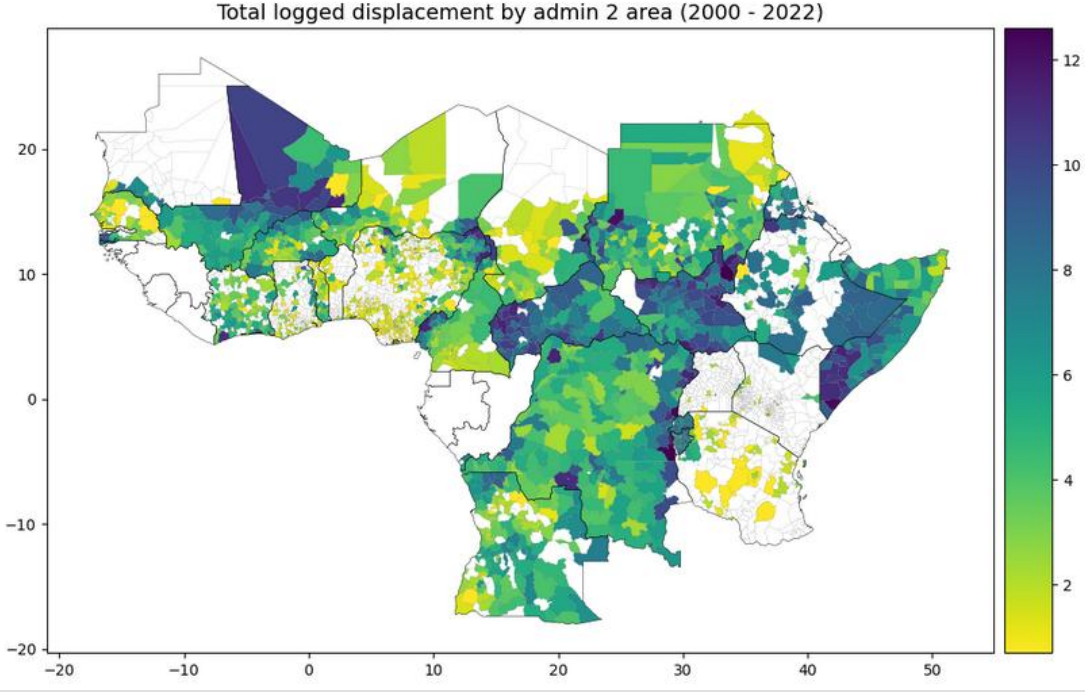
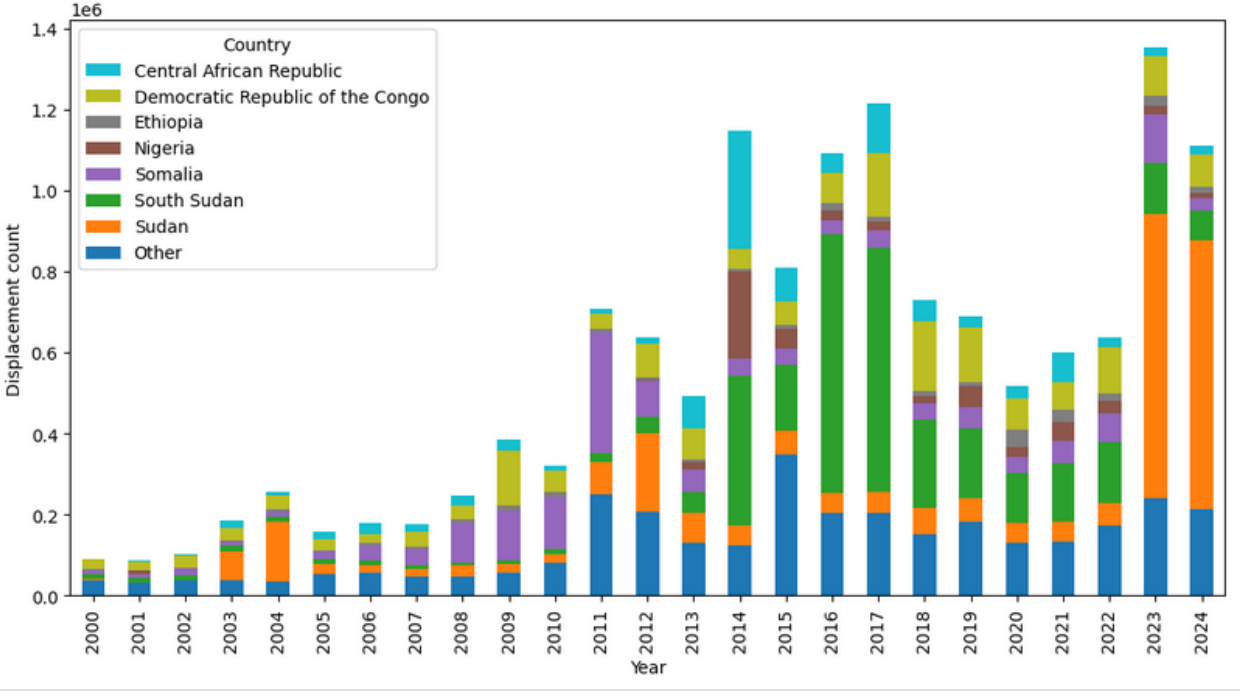
Target variable

Target: displacement

- UNHCR ProGres data
  - Registry of asylum seekers and refugees
  - Approximately 18 million observations, 13.9 million relevant to this project
- Based on sub-national information, observations are placed inside 0.5° grid-cells and aggregated to monthly time intervals





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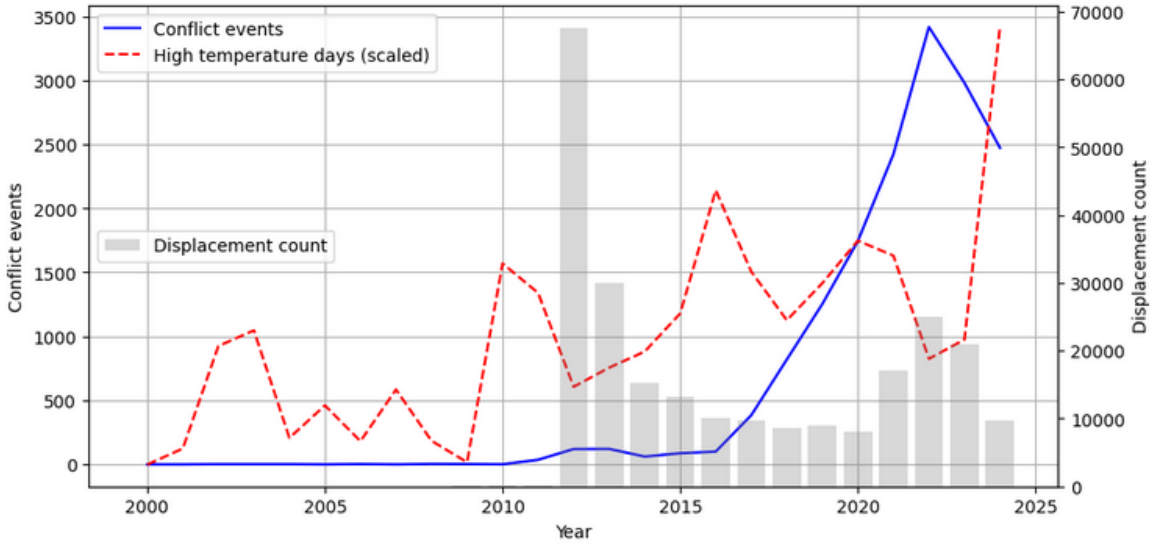
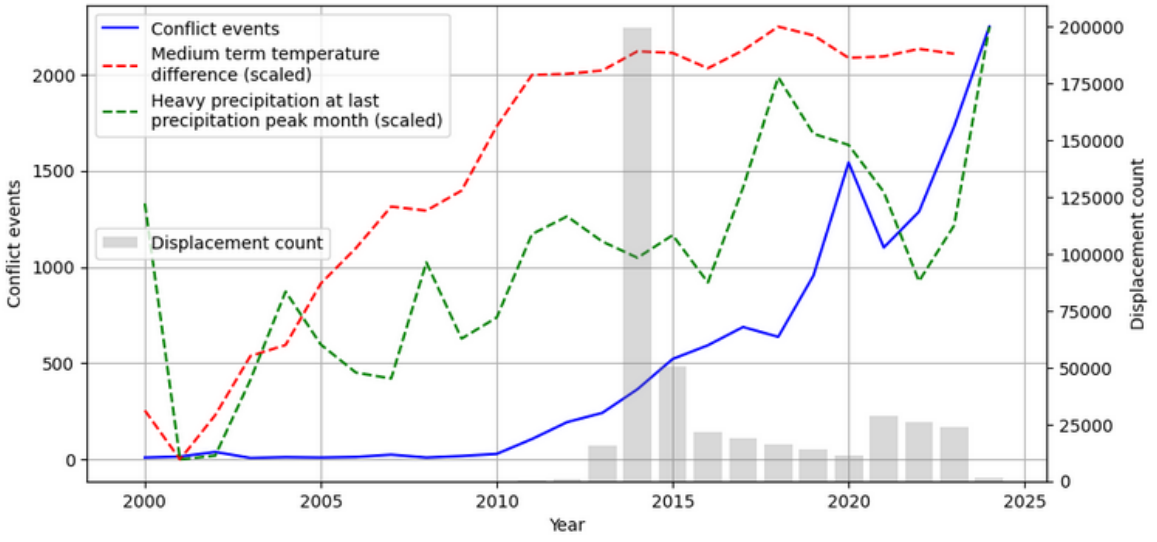
Target: displacement

Liptako-Gourma (Mali, Burkina Faso, Niger)



Lake Chad



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Predicting Forced Displacement Risk

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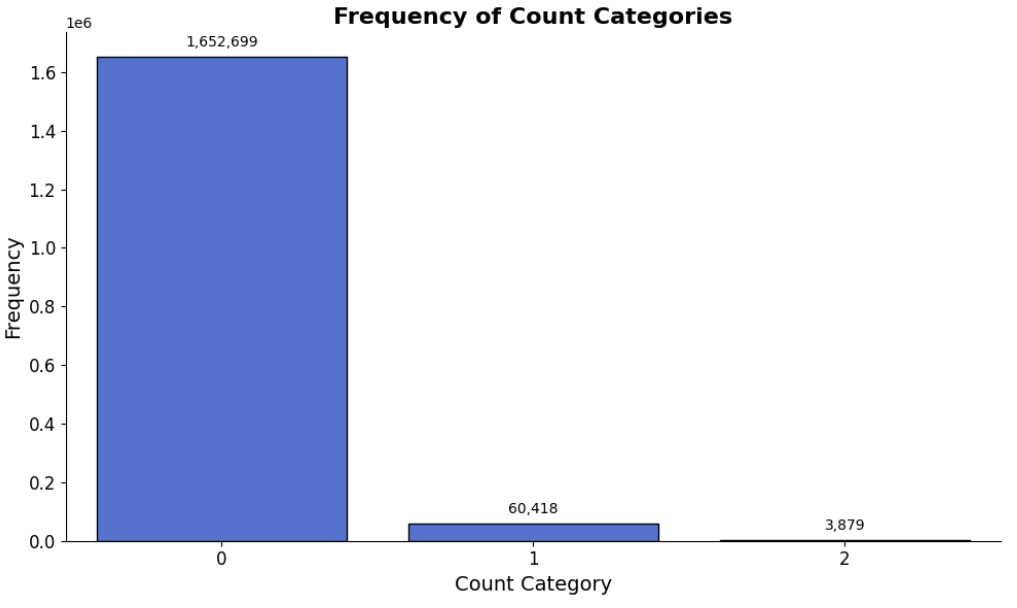
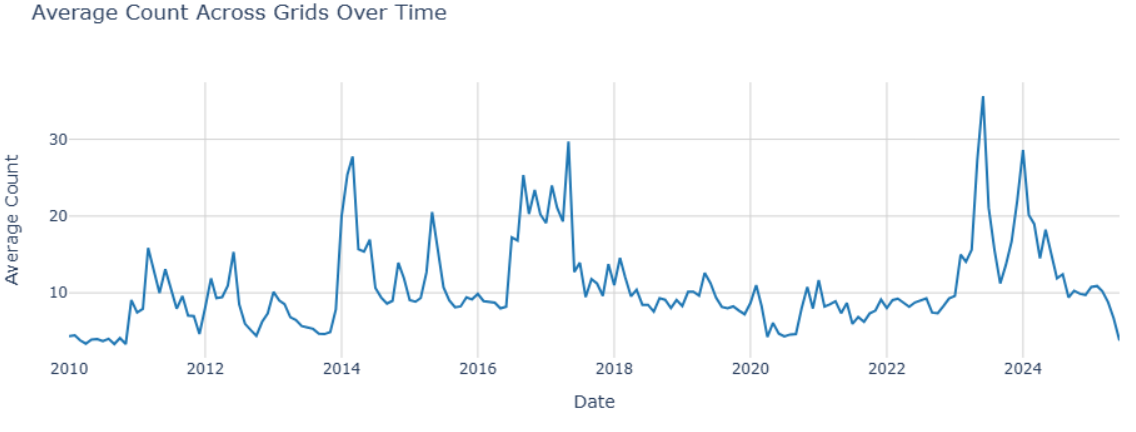
Response variable

- Cross-border movements, no IDPs (UNHCR data)
  - 1,757 of 6225 grid cells (28.2%) have experienced some displacement
- We have created three levels of forced displacement:
  - Class 0, (***low***, 0-9 forcibly displaced people)
  - Class 1, (***medium***, 10-500)
  - Class 2, (***high***, >500)
- We are predicting the probability of one of these levels occurring for each grid
  - we are predicting the risk of people fleeing ***from*** a grid
- We predict this for 1, 3, and 6 months into the future





Average displacement per grid cell from 2000 to 2025.

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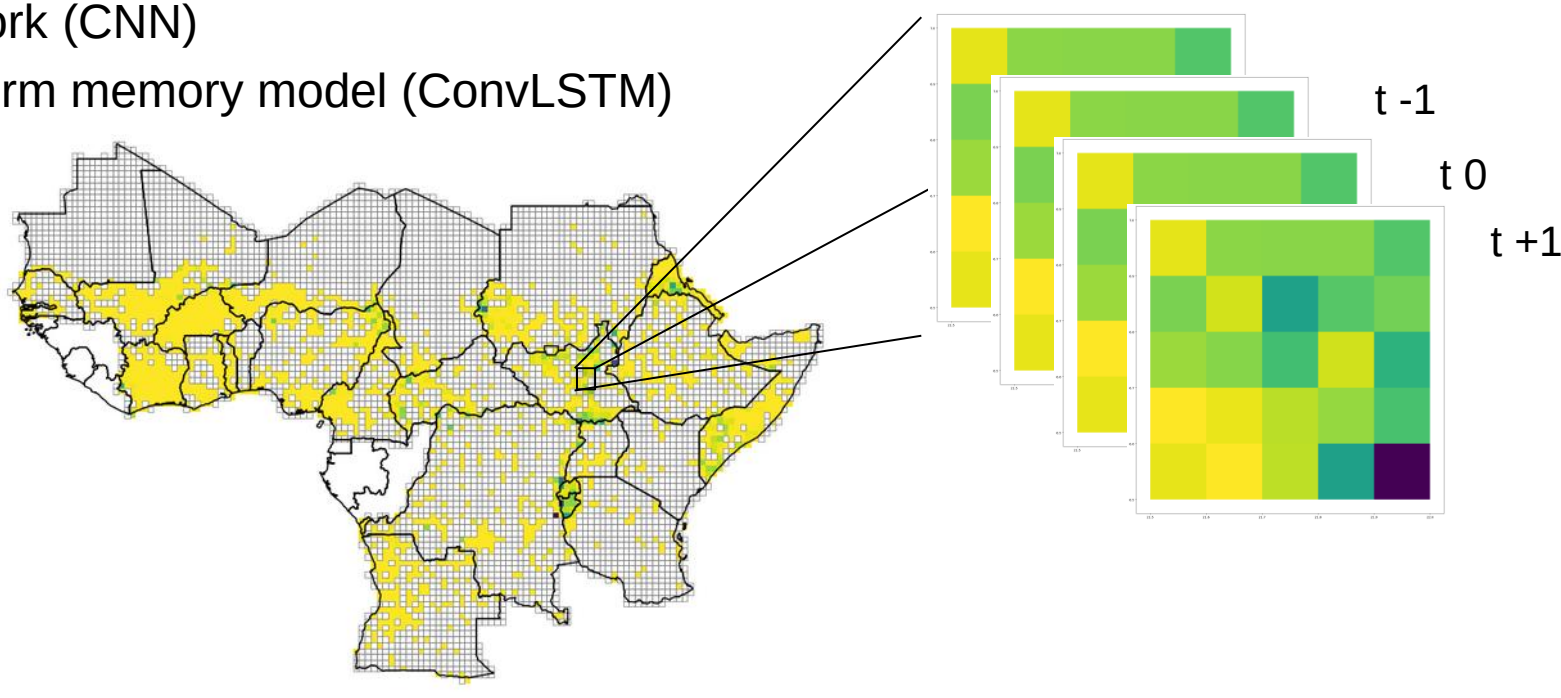
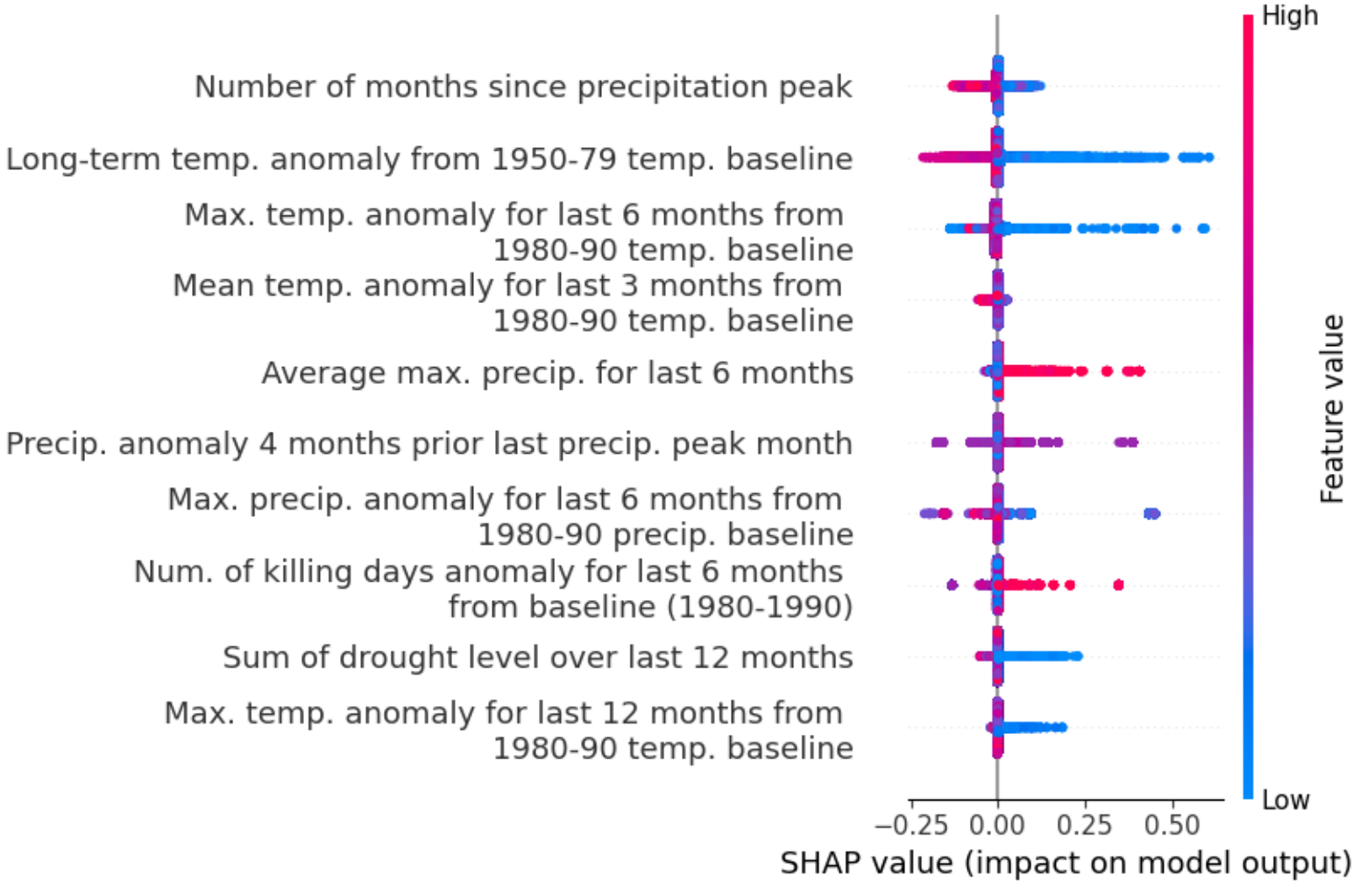
Models used

- We use an Ensemble model which combines different types of models
  - Baseline model
  - LightGBM model
  - Neural networks models
    - Convolutional neural network (CNN)
    - Convolutional long short-term memory model (ConvLSTM)
    - Hierarchical ConvLSTM
  - Ensemble models combines the strengths of all models to produce the most accurate predictions



Model findings

- LightGBM model predicting class 2 (>500) 6 months ahead
- Top 10 climate variables ranked by the highest average impact on the model predictions



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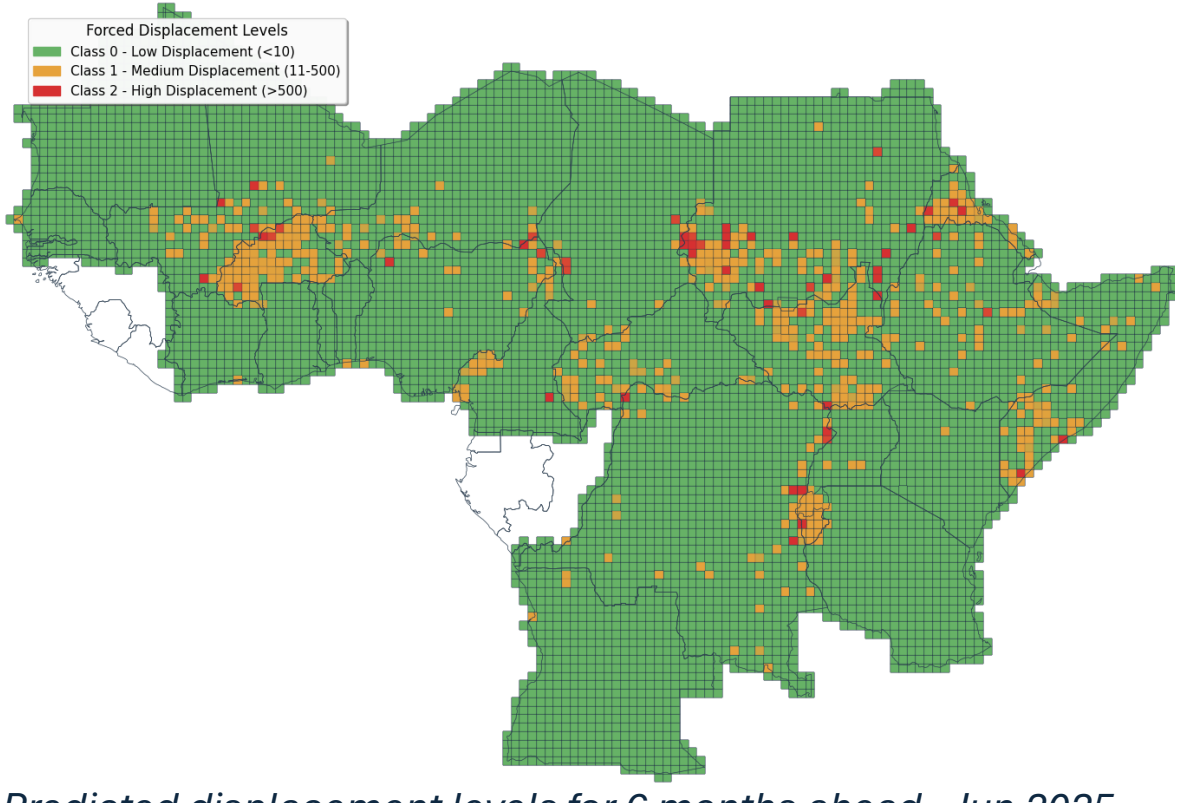
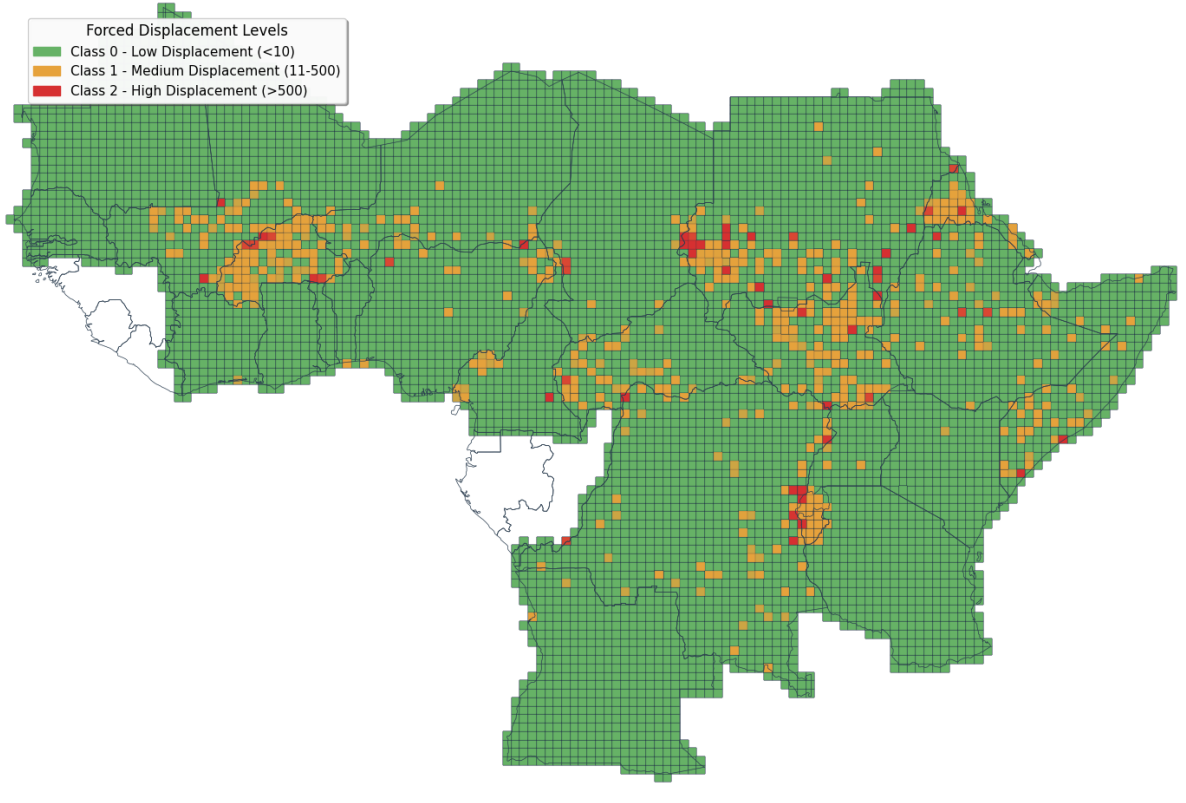
Model Evaluation

Class	Model	1 Month	3 Months	6 Months
0	Baseline	0.9952	0.9953	0.9956
	LightGBM	**0.9997**	**0.9997**	**0.9996**
	Simple convLSTM	0.9992	0.9993	0.9990
	CNN	0.9993	0.9991	0.9979
	Hierarch. convLSTM	0.9986	0.9980	0.9990
	Ensemble	*0.9988*	*0.9996*	*0.9995*
1	Baseline	0.8155	0.7838	0.7600
	LightGBM	**0.9138**	**0.8773**	**0.8386**
	Simple convLSTM	0.8561	0.7983	0.6918
	CNN	0.8292	0.7560	0.6682
	Hierarch. convLSTM	0.8318	0.7719	0.7241
	Ensemble	*0.8623*	*0.8516*	*0.8110*
2	Baseline	0.8049	0.7193	0.6547
	LightGBM	**0.8741**	*0.7519*	*0.6588*
	Simple convLSTM	0.7990	0.6807	0.4819
	CNN	0.8167	0.6691	0.5630
	Hierarch. convLSTM	0.7625	0.6811	0.5839
	Ensemble	*0.8240*	**0.7570**	**0.6841**

Model Evaluation



Predicted displacement levels for 6 months ahead - Jun 2025



Actual displacement levels - Jun 2025

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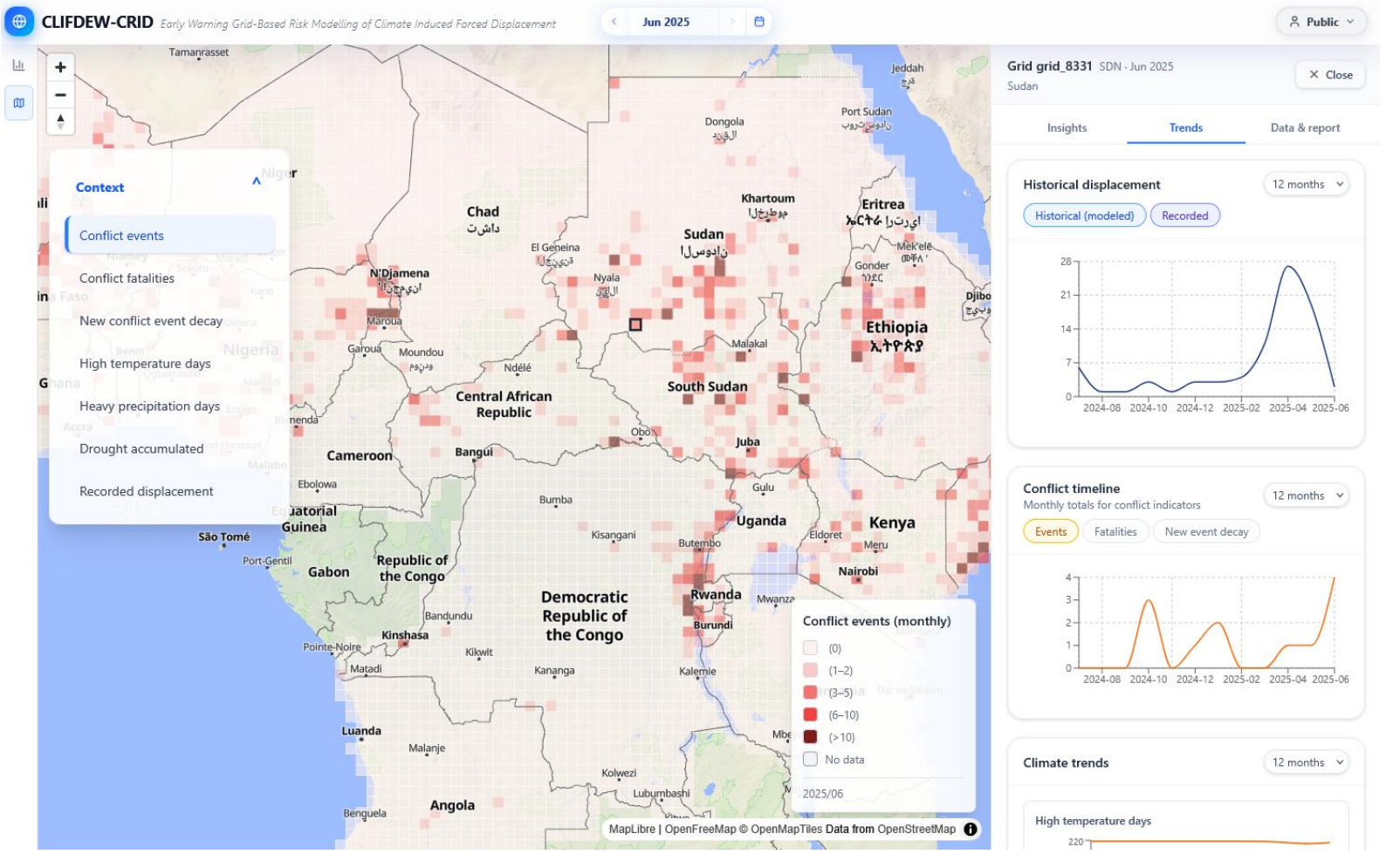
Product

Product

- Dashboard



Global Early Warning System

Strengthening preparedness and response in complex humanitarian emergencies.

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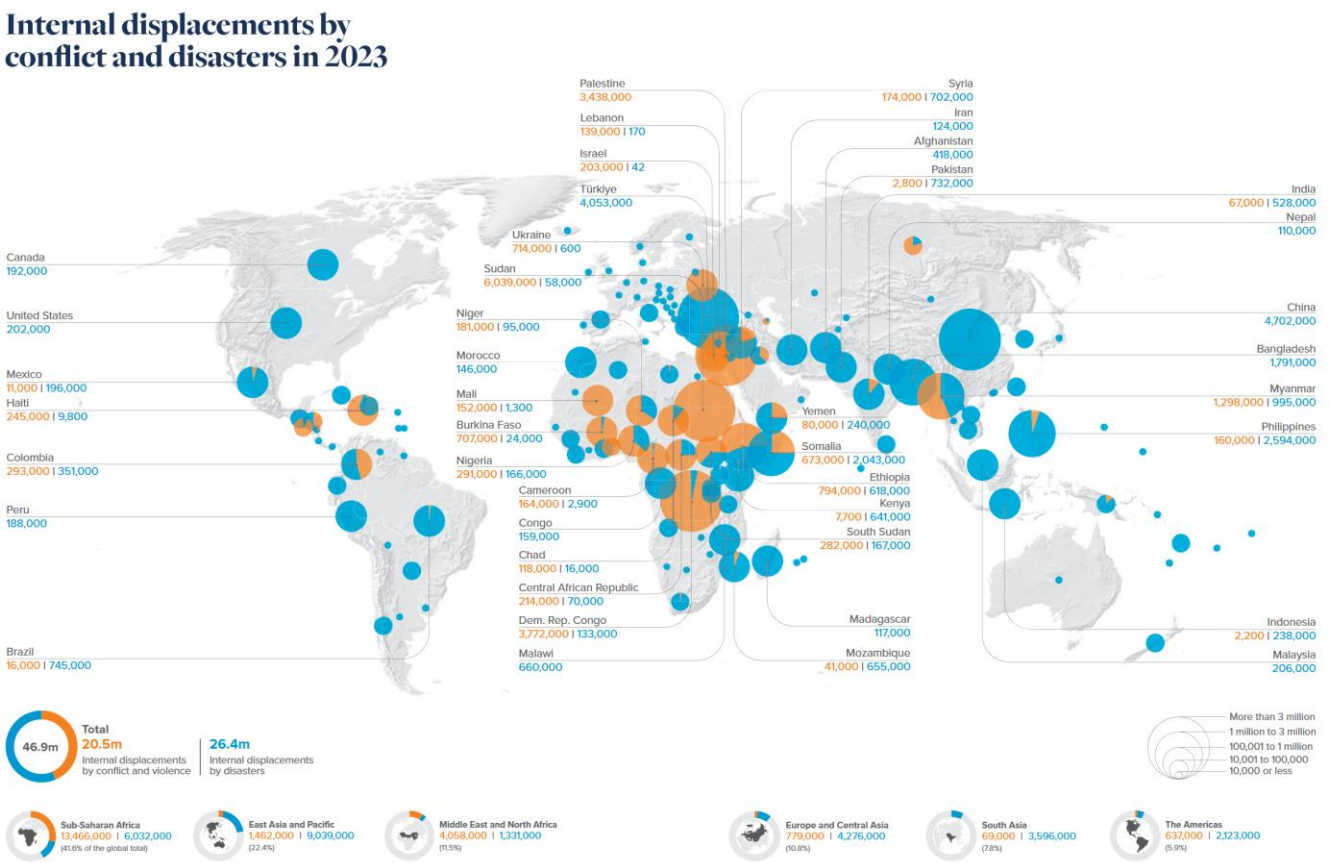
Background

- Conflict and violence triggered 20.5 million new internal displacements, across 45 countries.
- Disasters triggered 26.4 million new intern displacements across 148 countries.

- EWERS is funded by the Ministry of Foreign Affairs in Luxembourg.
- Collaboration between LIST and UNHCR.



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Goal | Impact - Displacement forecasting

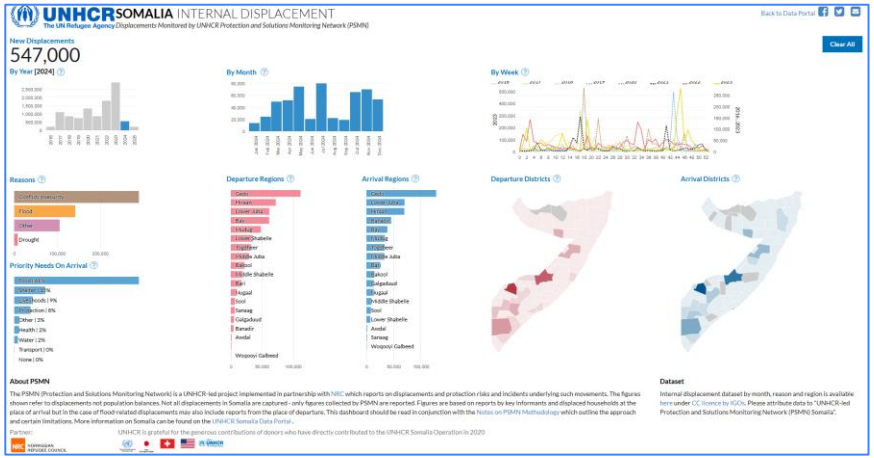
We aim to predict **where/when/magnitude** of potential displacement 1 – 2 weeks in advance

Displacement induced by floods (2025), conflict, and tropical cyclone

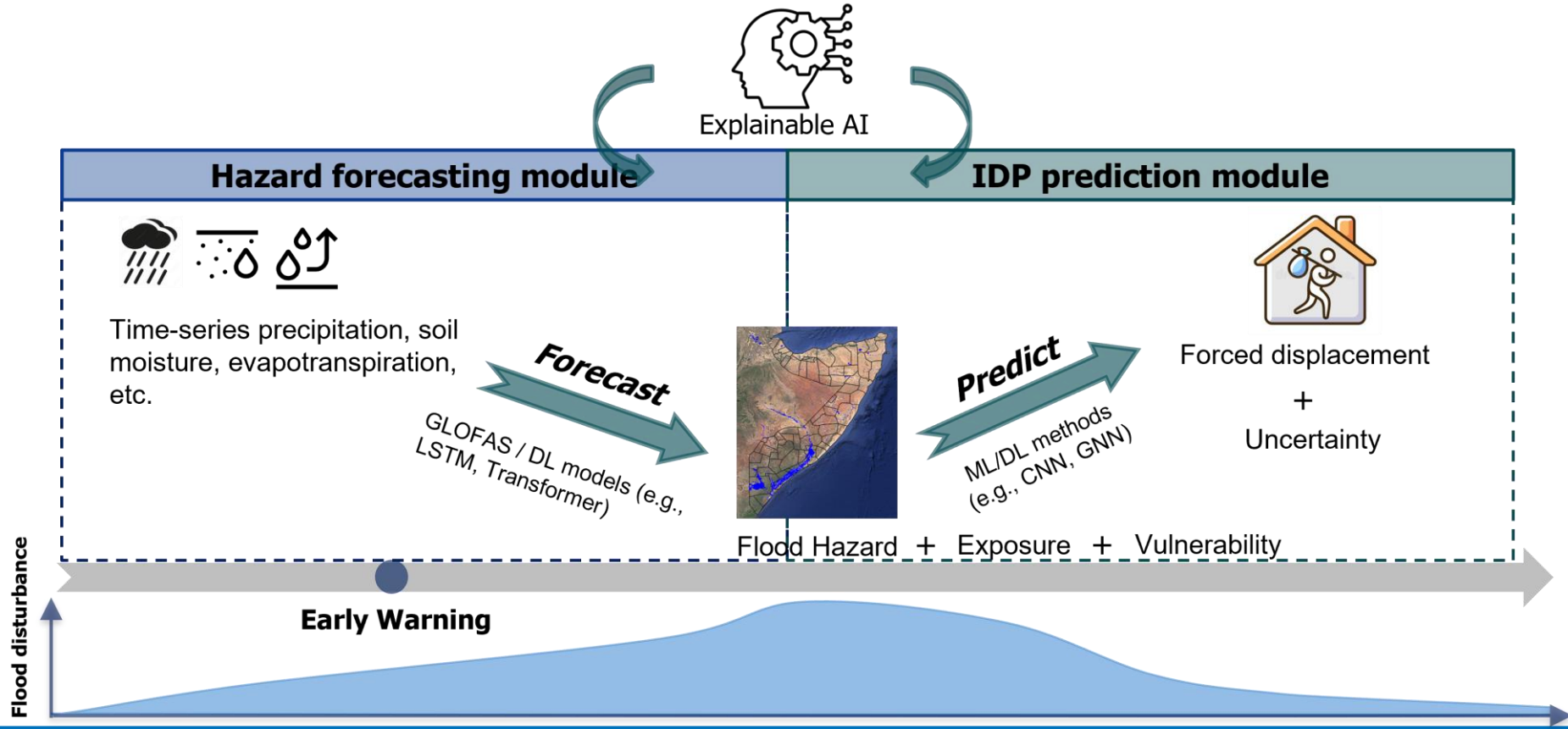
- ✓ Provide early warning
- ✓ Targeted preparedness actions
- ✓ Minimize response times
- ✓ Optimize supply process
- ✓ Avoid the duplication of humanitarian efforts
- ✓ Result in more life saving
- ✓ Achieve resource saving

Prototype in Somalia

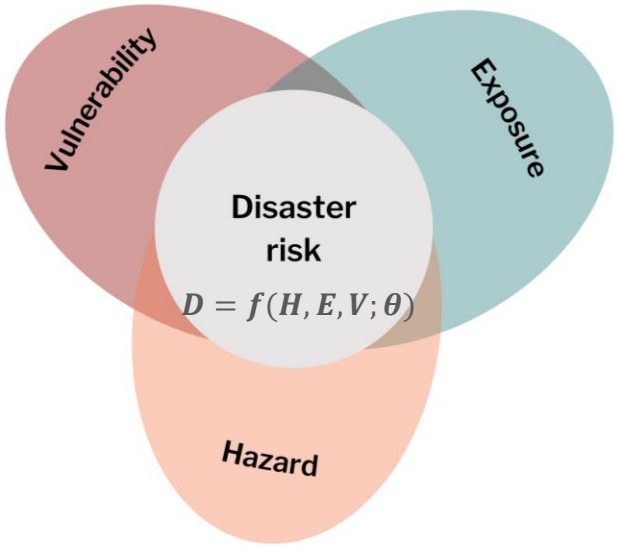
- UNHCR places Somalia **seventh** globally in terms of **displaced populations**
- Existing **internal displacement data** with solid support from country-based colleagues
- Cyclic flood causing forced internal **displacement**
- Challenge to address **complex overlapping drivers** of displacement



Impact-based Forecasting & Anticipatory Action



Impact-based Forecasting & Anticipatory Action



$$D = f(H, E, V; \theta)$$

D: IDP to be predicted

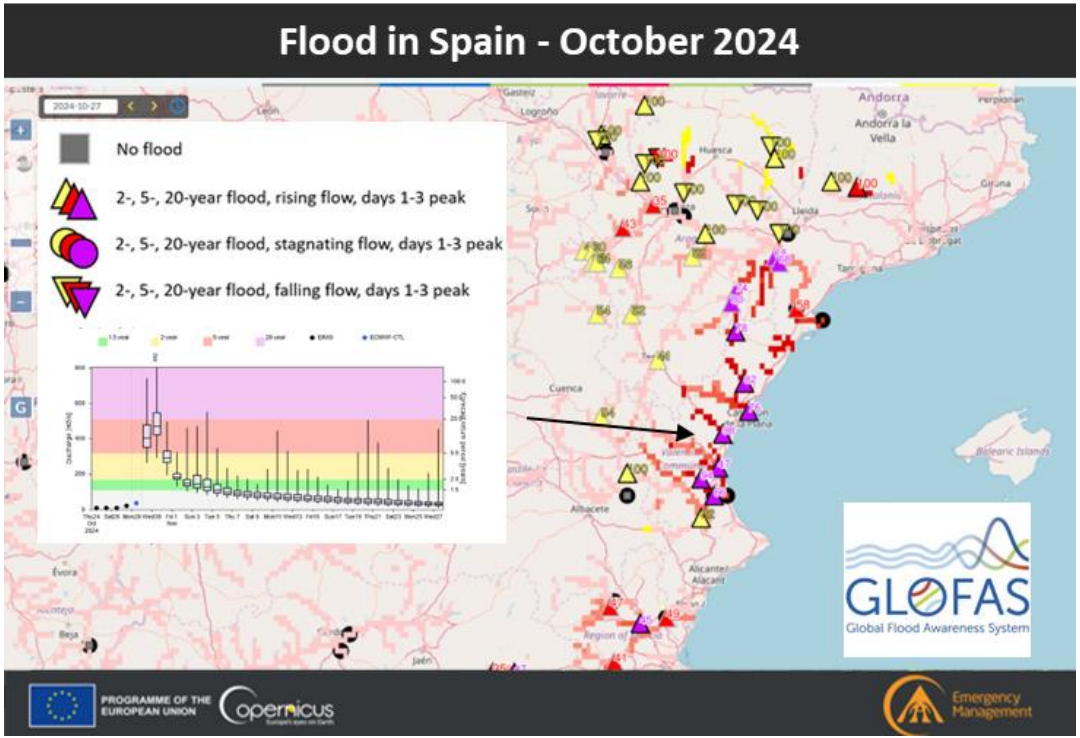
H: Hazard intensity (e.g., flood depth, precipitation)

E: Exposure (e.g., population, building)

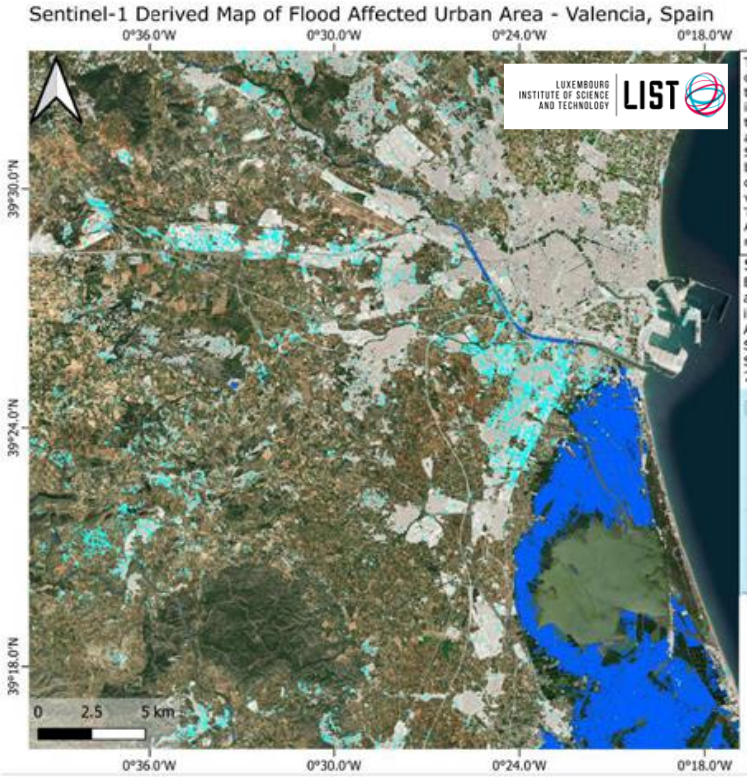
V: Vulnerability (e.g., socioeconomic and environmental factors)

$f(\theta)$: Impact function (e.g., neural networks with parameters θ)

Flood monitoring & forecasting



Flood prediction model



Satellite-based observation of flood extent

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Data Preparation

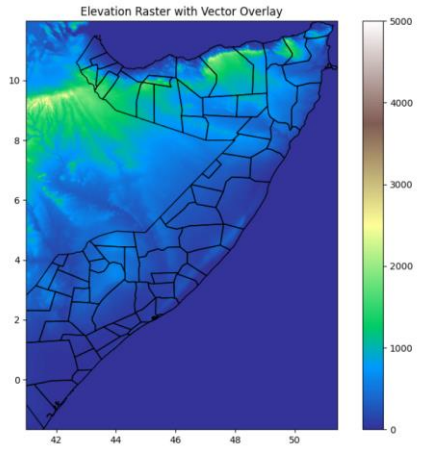
Hazard | Exposure | Vulnerability | IDP

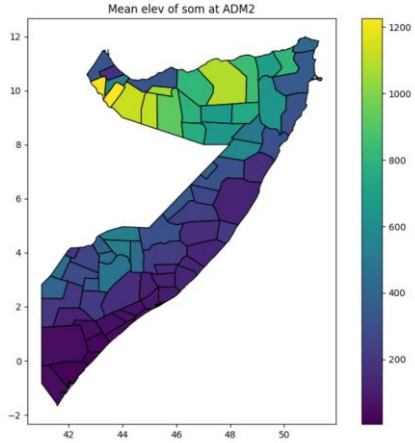
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Month End	Year	YrWeek	Current	Current	Previous	Previous	Reason	PriorityN	Discharg	Water depth	Precipita	Populatic	Building Fraction	AWI	Agricultural land	TotalIndividuals	
1489	30/04/2016	2016	201616	Awdal	Borama	Awdal	Borama	Flood	Food								5	
1684	31/05/2016	2016	201618	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								135	
1685	31/05/2016	2016	201618	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								144	
1694	31/05/2016	2016	201619	Lower Juba	Jamaame	Lower Juba	Jamaame	Flood	Shelter								133	
1697	31/05/2016	2016	201618	Middle Sha	Jowhar	Middle Sha	Jowhar	Flood	Other								810	
1700	31/05/2016	2016	201619	Bakool	Ceel Barde	Bakool	Ceel Barde	Flood	Food								150	
1711	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								6	
1712	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1713	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								4	
1734	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								119	
1757	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								495	
1758	31/05/2016	2016	201619	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								227	
1841	31/05/2016	2016	201620	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1842	31/05/2016	2016	201620	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1843	31/05/2016	2016	201620	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1860	31/05/2016	2016	201620	Mudug	Gaalkacyo	Hiraan	Belet Weyn	Flood	Livelihood								6	
1914	31/05/2016	2016	201620	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								325	
1962	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								7	
1963	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								4	
1964	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1965	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								6	
1966	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
1968	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								8	
1980	31/05/2016	2016	201621	Mudug	Gaalkacyo	Hiraan	Belet Weyn	Flood	Other								8	
1988	31/05/2016	2016	201621	Bakool	Tayeeglow	Hiraan	Belet Weyn	Flood	Food								183	
1999	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								5	
2000	31/05/2016	2016	201621	Middle Jub	Saakow	Middle Jub	Saakow	Flood	Food								4	

- **Weekly IPD data:** UNHCR-PSMN project
- **Hazard information**: river discharge from GLOFAS, precipitation from ECMWF/ERA5
- **Exposure:** population density, built-up area, elevation, crop land
- **Vulnerability:** poverty (e.g., HDI, IWI, GINI), conflict situation

Data Preparation

Extraction of topography at Admin-2 level



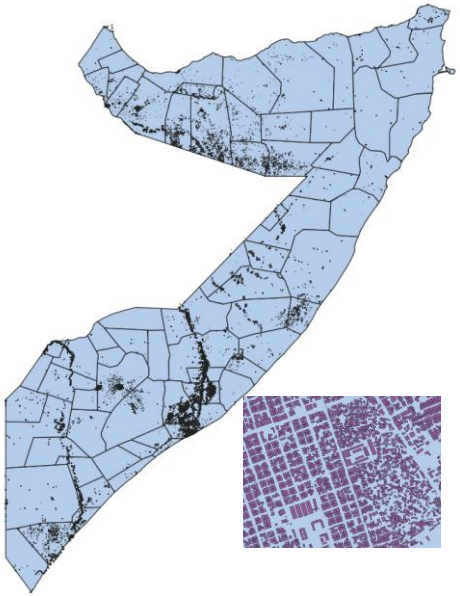


	A	B	C
1	**ADM2_EN**	**ADM2_PCODE**	**mean_DEM**
2	Baki	SO1102	536.211
3	Borama	SO1101	1213.777
4	Lughaye	SO1103	181.838
5	Zeylac	SO1104	332.345
6	Ceel Barde	SO2502	525.27
7	Rab Dhuure	SO2505	370.443
8	Tayeeglow	SO2503	426.706
9	Waajid	SO2504	444.333
10	Xudur	SO2501	527.783
11	Bondhere	SO2201	30.438
12	Cabdulasis	SO2202	4.438
13	Daynile	SO2203	100.999
14	Dharkenley	SO2204	45.752
15	Hamar Jabjab	SO2205	17.438
16	Hamar Weyne	SO2206	8.875
17	Hawl Wadaag	SO2207	51.062
18	Heliwa	SO2208	39.514
19	Hodan	SO2209	66.062

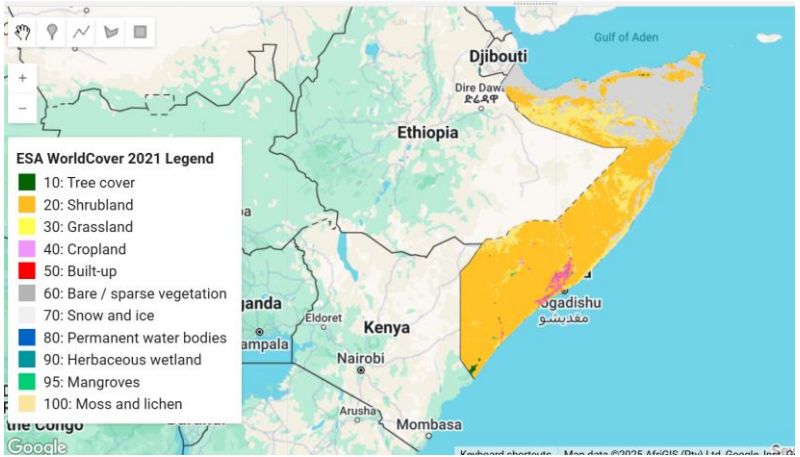
Topography—through variations in elevation —shapes how floodwaters spread across a landscape,
affecting which areas are inundated, how severely populations are impacted, and where displacement is most likely to occur.

Data Preparation

Building footprint



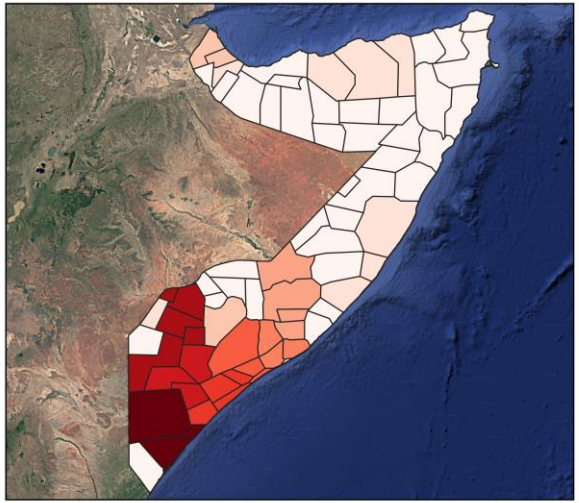
Landcover



Sources : OpenStreetMap / ESA WorldCover

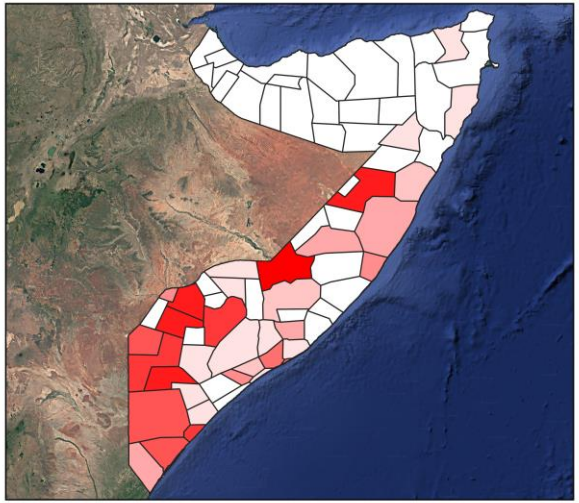
Data Preparation

GLOFAS discharge



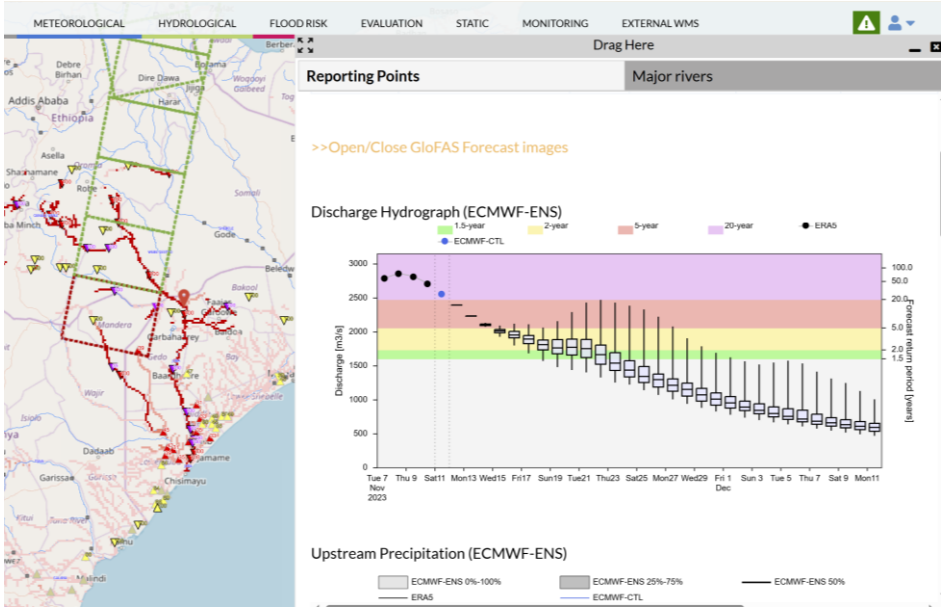
GLOFAS 2-day leadtime forecast (cumecs)
- 0 - 1.4
- 1.4 - 5.8
- 5.8 - 163.9
- 163.9 - 573.1
- 573.1 - 589.6
- 589.6 - 636
- 636 - 2297.3
- 2297.3 - 2374.4
- 2374.4 - 2391.3
- 2391.3 - 2905

Flood-induced IDP in November 2023 from UNHCR-PSMN

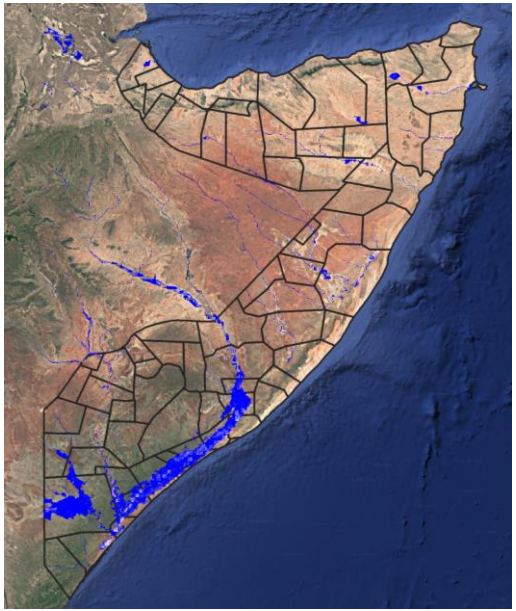


Flood-induced IDP from UNHCR-PRMN
- 0 - 300
- 300 - 2000
- 2000 - 4000
- 4000 - 6000
- 6000 - 15000
- 15000 - 22000
- 22000 - 46000
- 46000 - 84000
- 84000 - 195000
- 195000 - 225000

Data Preparation



GLOFAS discharge forecast

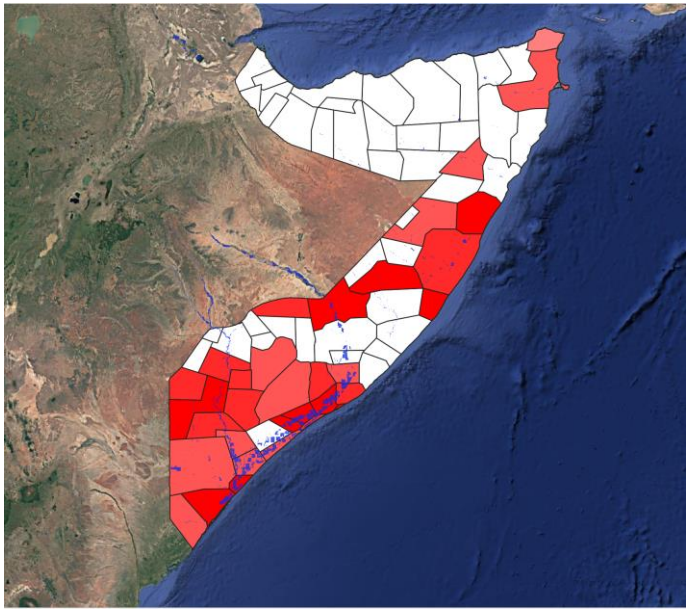


Flood Water Depth

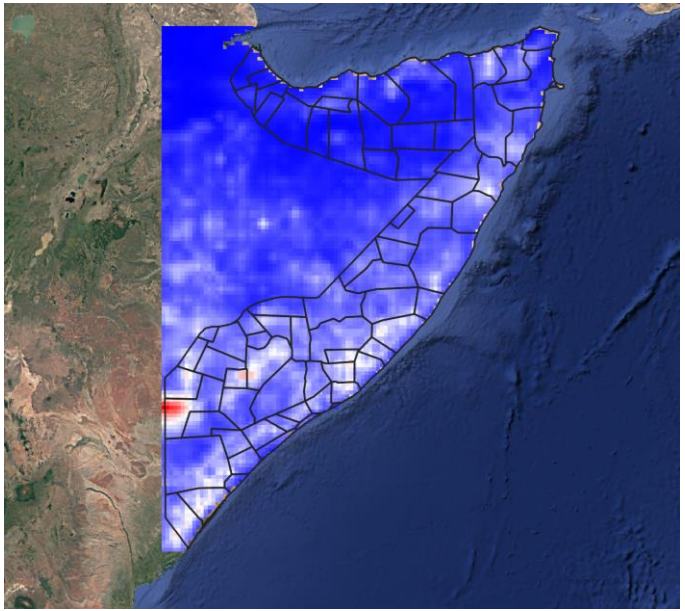
Data Preparation

Week 2023-36, starts at 12/11/2023

Water depth >= 10 cm on top of IDP records



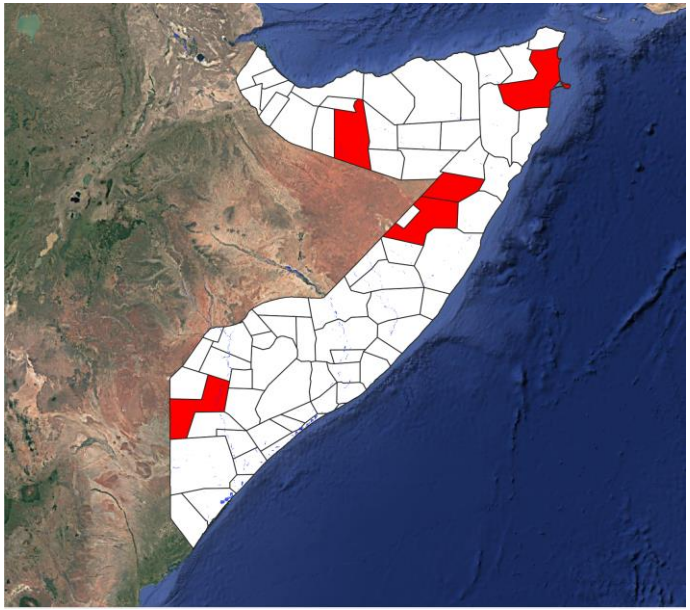
Maximum precipitation



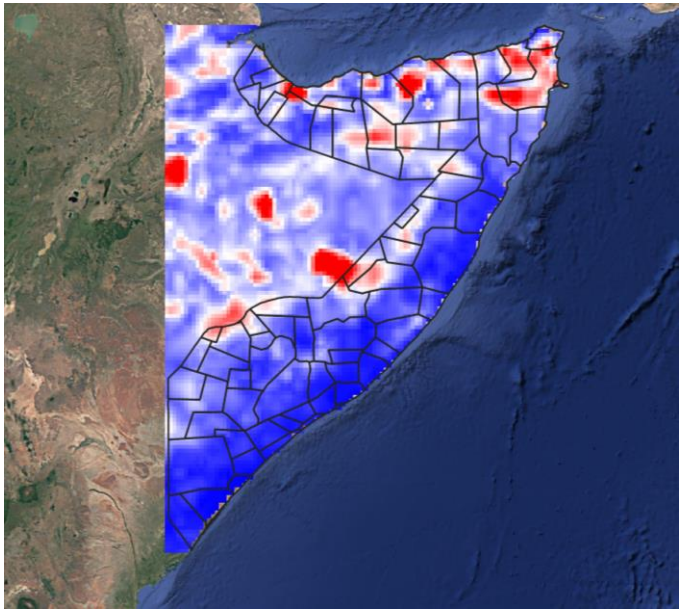
Data Preparation

Week 2023-12, starts at 19/03/2023

Water depth >= 10 cm on top of IDP records



Maximum precipitation



Data Preparation

FLOOD	EXPOSURE	VULNERABILITY
Environmental and climatic triggers of displacement	Population and assets located in hazard zones	Ability to prepare for, respond to, and recover from displacement
🔴 **Riverine flood – Flood fraction** (GloFas) 🔴 **Precipitation** (ERA5) 🔴 **Wind speed** (ERA5) 🔴 **Soil Moisture** (ERA5) 🔴 **Convective available potential energy (CAPE)** (ERA5) 🔴 **Air Temperature** (ERA5) 🔴 **Evaporation** (ERA5)	🟢 **Demographics** (Age groups proportion -WorldPop) 🟢 **Building density** (ESA WorldCover) 🟢 **Populated area** (HDX) 🟢 **Topography** (Elevation — Earthenv) 🟢 **Travel time to the nearest market** (HDX) 🟡 **Week Number**	🟢 **Poverty and income** *(HDI, IWI— World Bank, UNDP)* 🟡 **Conflict exposure** *(conflict fatalities - ACLED)*

🟢 Static or Annual Updates

🟡 Weekly or Frequent Updates - cannot be forecasted but can be integrated into the model actively.

🔴 Forecasted Variables - can be used to predict displacement before it happens.

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Modeling Experiments

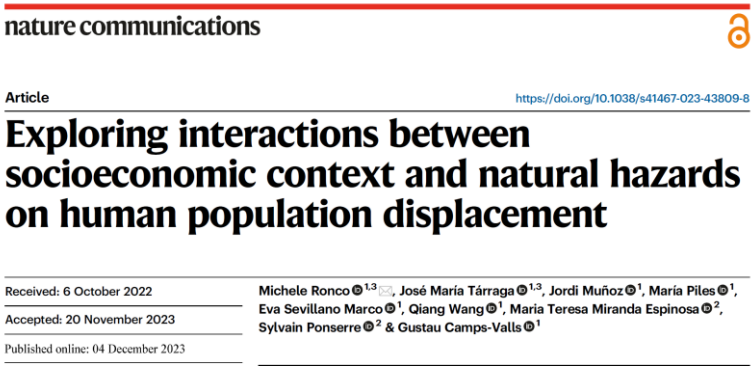
- **IDP data (**PSMN, 2016-2025): data between 2019-2024 (1109 weekly records) is used for experiments (GLOFAS flood forecast is only available from 2019).

- **Target:** One week lead time IDP forecast.

- **Experiments:** Bootstrapping with 100 resampling for hypothesis test and model comparison, with 80/20 data random split of training and test dataset for each running.

Modeling Experiments

State of the art



nature communications

Article

https://doi.org/10.1038/s41467-023-43809-8

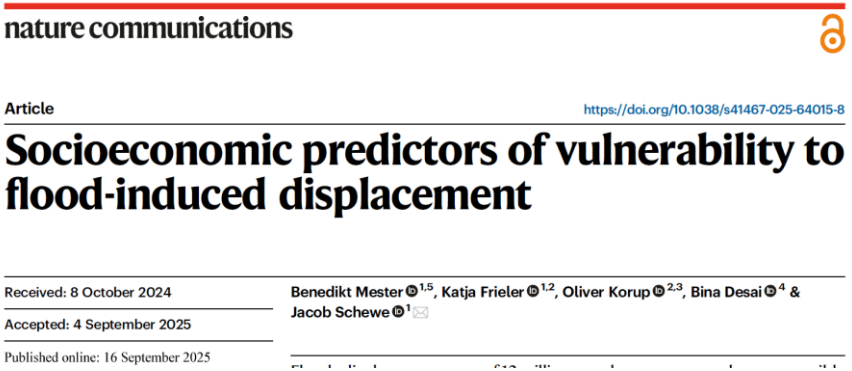
Exploring interactions between socioeconomic context and natural hazards on human population displacement

Received: 6 October 2022

Accepted: 20 November 2023

Published online: 04 December 2023

Michele Ronco[1,3], José María Tárraga[1,3], Jordi Muñoz[1], María Piles[1], Eva Sevillano Marco[1], Qiang Wang[1], Maria Teresa Miranda Espinosa[2], Sylvain Ponserre[2] & Gustau Camps-Valls[1]



nature communications

Article

https://doi.org/10.1038/s41467-025-64015-8

Socioeconomic predictors of vulnerability to flood-induced displacement

Received: 8 October 2024

Accepted: 4 September 2025

Published online: 16 September 2025

Benedikt Mester[1,5], Katja Frieler[1,2], Oliver Korup[2,3], Bina Desai[4] & Jacob Schewe[1]

- Based on real observations
- Admin 1 to national level, global scale
- Random Forest

R^2: ~ 0.31

R^2: 0.28-0.34

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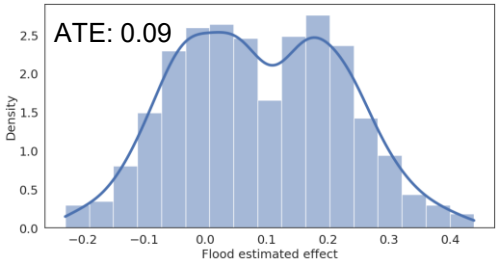
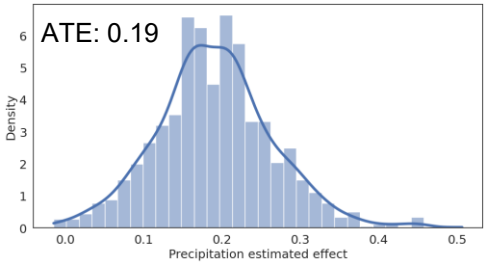
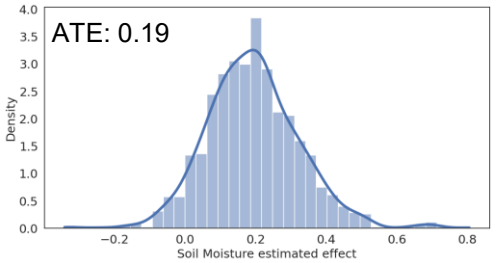
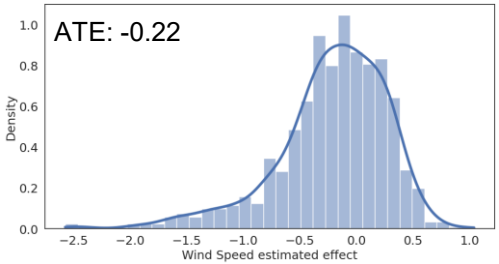
Modeling Experiments

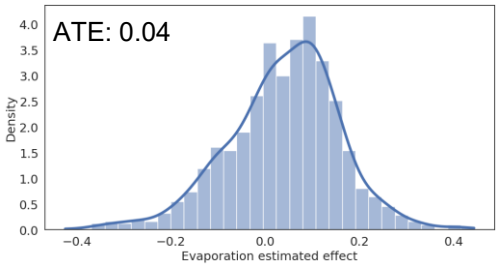
Causal effect estimation of weather-related variables through double machine learning



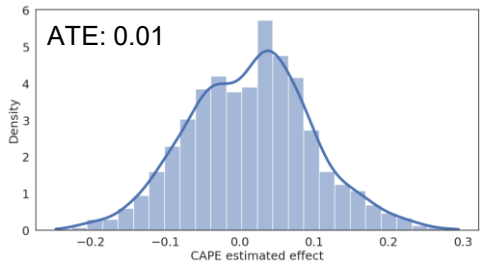


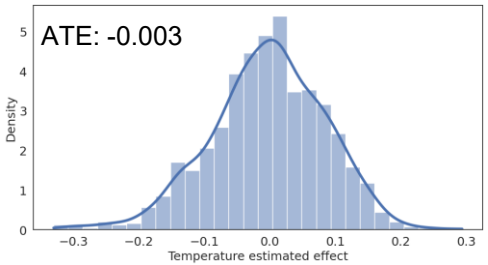






ATE: Average Treatment Effect





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Modeling Experiments

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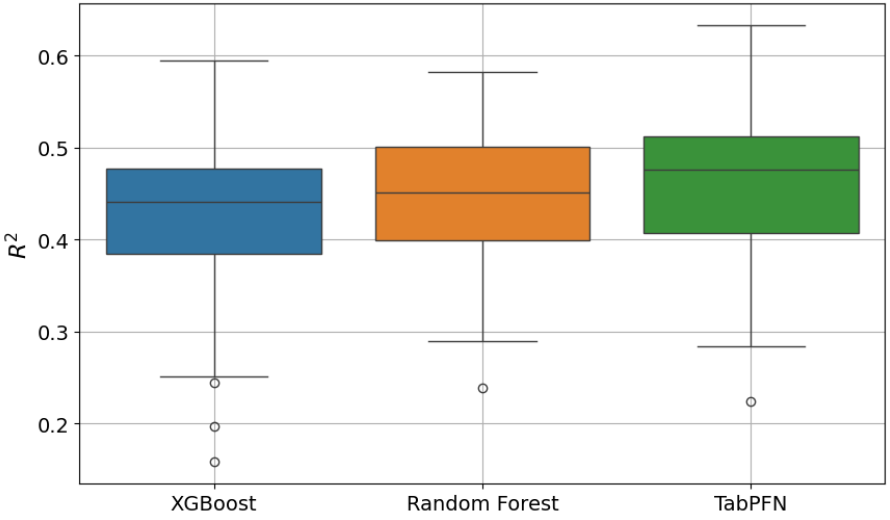
🟡 Weekly or Frequent Updates - cannot be forecasted but can be integrated into the model actively.

🔴 Forecasted Variables - can be used to predict displacement before it happens.

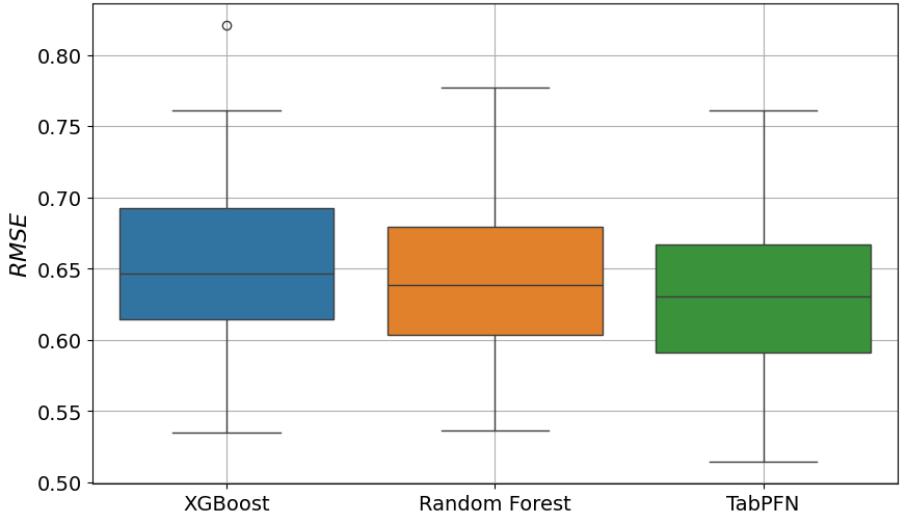
Modeling Experiments

Regression models comparison

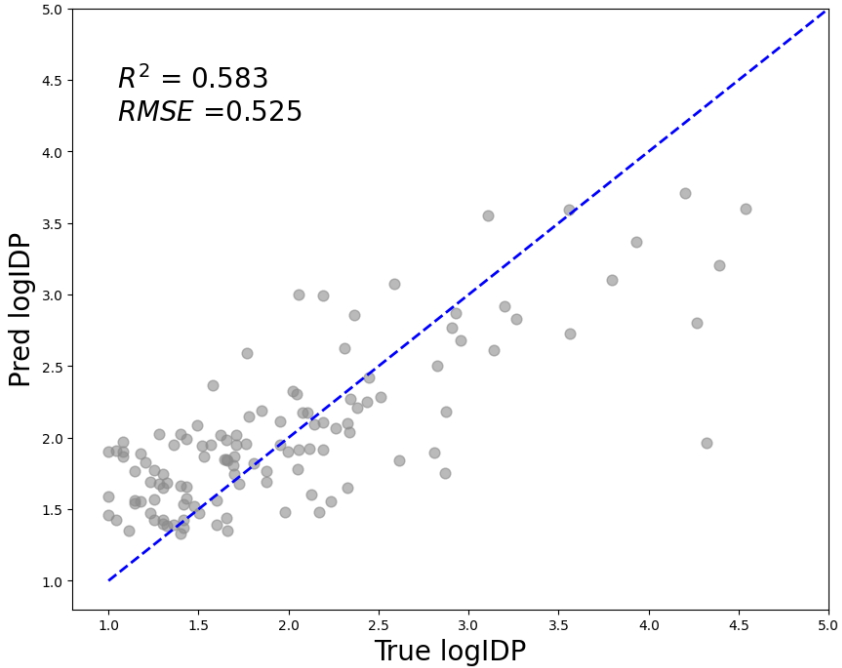
R^2: 0.42 $\pm$0.08 0.44 $\pm$0.07 0.46 $\pm$0.08



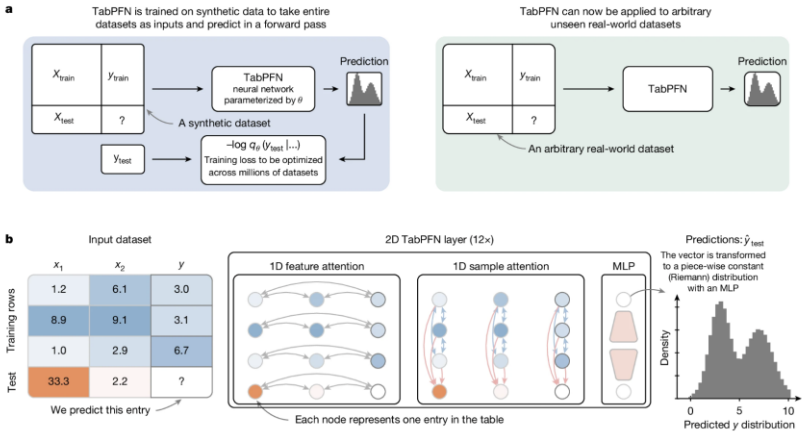
RMSE: 0.65 $\pm$0.06 0.64 $\pm$0.05 0.62 $\pm$0.07



Modeling Experiments



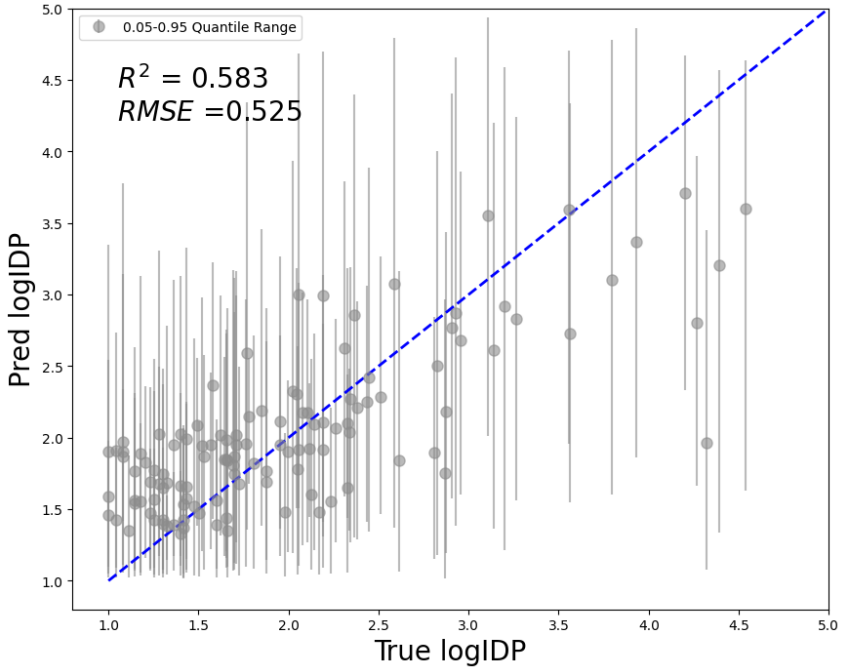
TabPFN



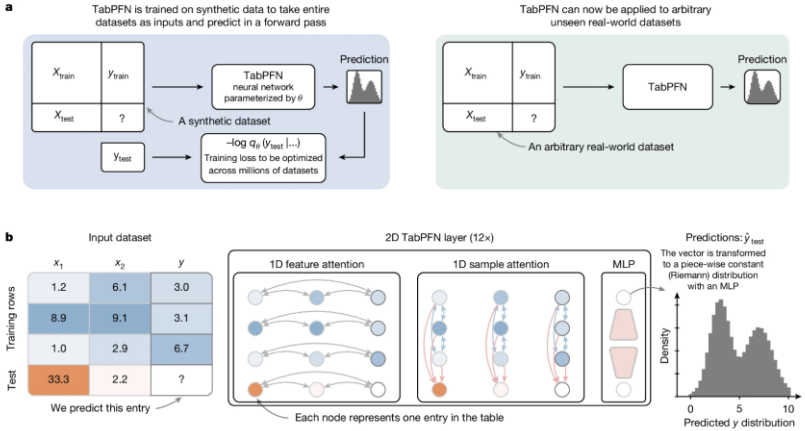
- Pretrained tabular foundation model using synthetical data generated through causal models
- In-context learning

- Over-estimation in small events (e.g., IDP < 100), under-estimation in large events (e.g., IDP > 5000)

Modeling Experiments



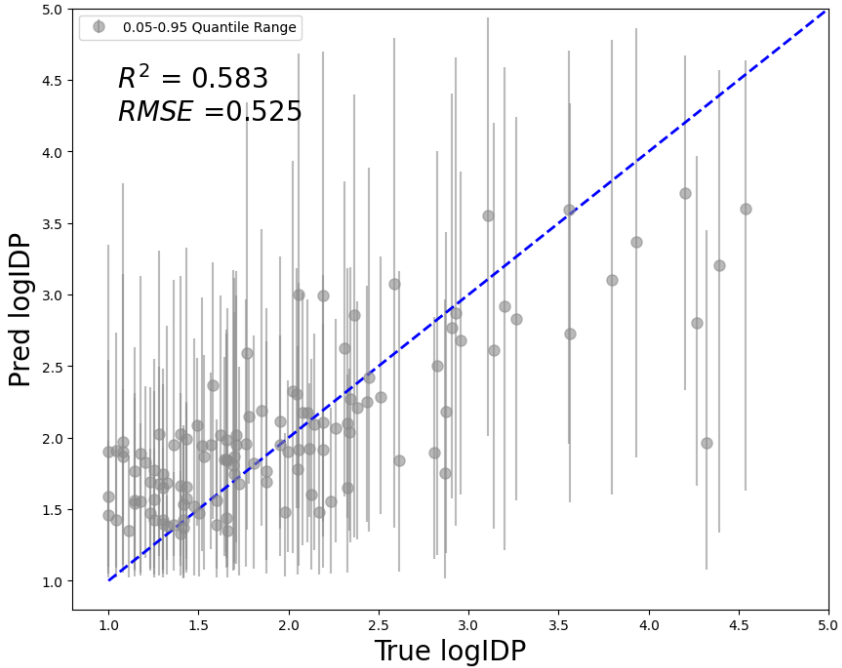
TabPFN



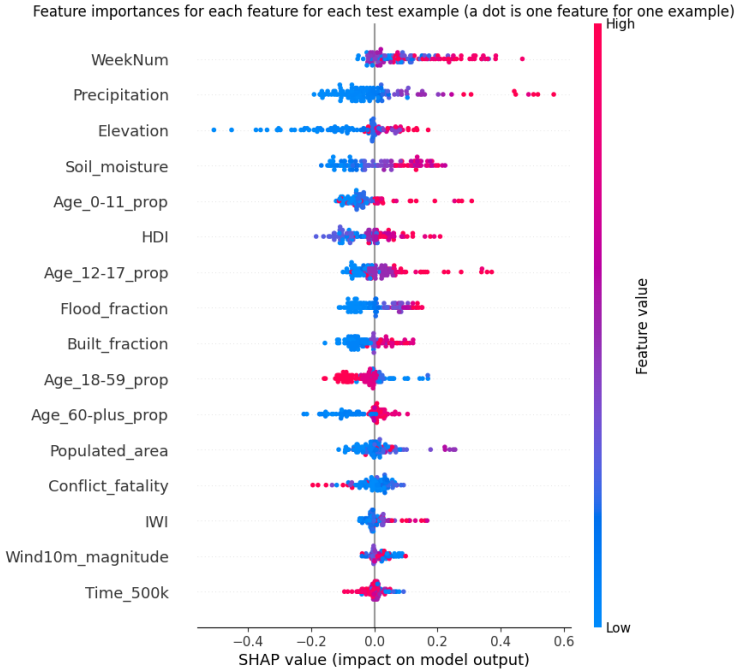
- Pretrained tabular foundation model using synthetical data generated through causal models
- In-context learning

- Over-estimation in small events (e.g., IDP < 100), under-estimation in large events (e.g., IDP > 5000)
- Apply 5% and 95% quantile regression to offer 90% prediction interval

Modeling Experiments



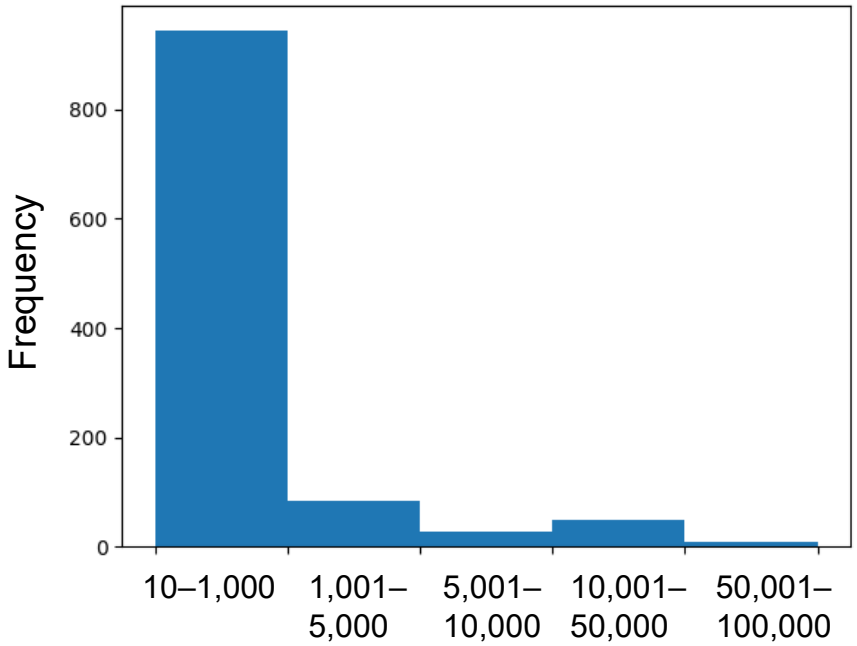
SHAP based prediction explanation



- Over-estimation in small events (e.g., IDP < 100), under-estimation in large events (e.g., IDP > 5000)
- Apply 5% and 95% quantile regression to offer 90% prediction interval

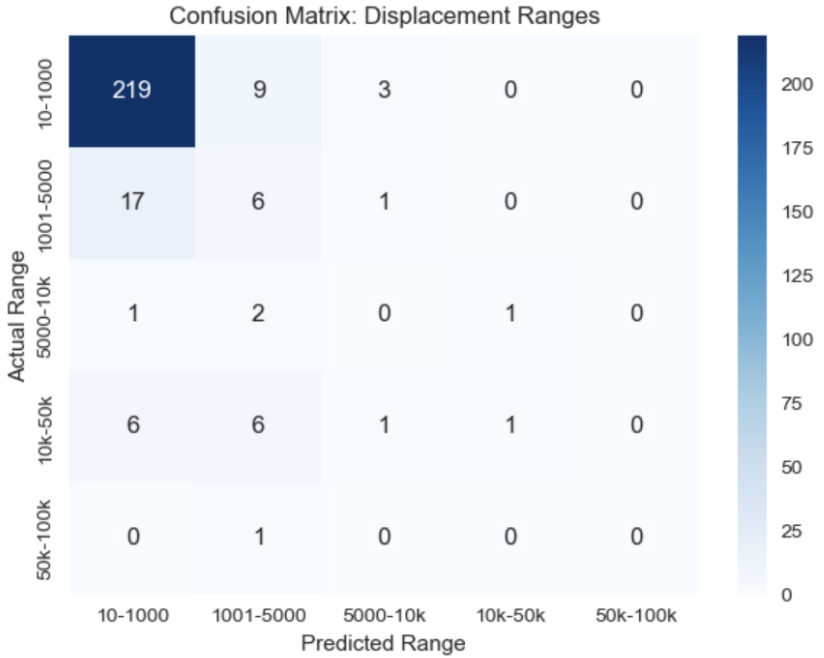
Modeling Experiments

- Categorize IDP into ranges based on several operational thresholds
- Dadaset is severely skewed to small events (e.g., IDP < 1000)



Modeling Experiments

- Evaluation on IDP ranges shows high accuracy in classifying small events with IDP < 1000.
- Performance drops dramatically in large events.
- Overall accuracy: 0.82 – dominated by small events.



Roadmap

- Enhance IPD data collection: IDMC disaggregated data is supposed to be released in Feb 2026.
- Have a better understanding of root causes of IDP: close collaboration with UNHCR and local authorities.
- Integrate other important social-economic and environmental predictors that are currently ignored.
- Improve Flood forecast accuracy: GLOFAS v 5.0 will be in place in April 2026. Account for both riverine and flash flood: Google flash flood model will be released in early 2026.
- Test model generalization across different countries (e.g., Chad, CAR)
- Investigate IDP induced by other hazards as well as armed conflict.

Thank you!

Asuka Imai, Senior Project Manager (imai@unhcr.org)

Ines Krissaane Ph.D. Associate Data Scientist

Patrick Matgen, Group Leader (patrick.matgen@list.lu)

Yu Li, Senior R&D Scientist (yu.li@list.lu)

Thanh Huy Nguyen, Senior R&D Scientist

Aolin Jia, R&D Scientist

With the support of

GDS UNHCR

Innovation UNHCR

UNHCR Somalia PSMN Displacement and Protection Information

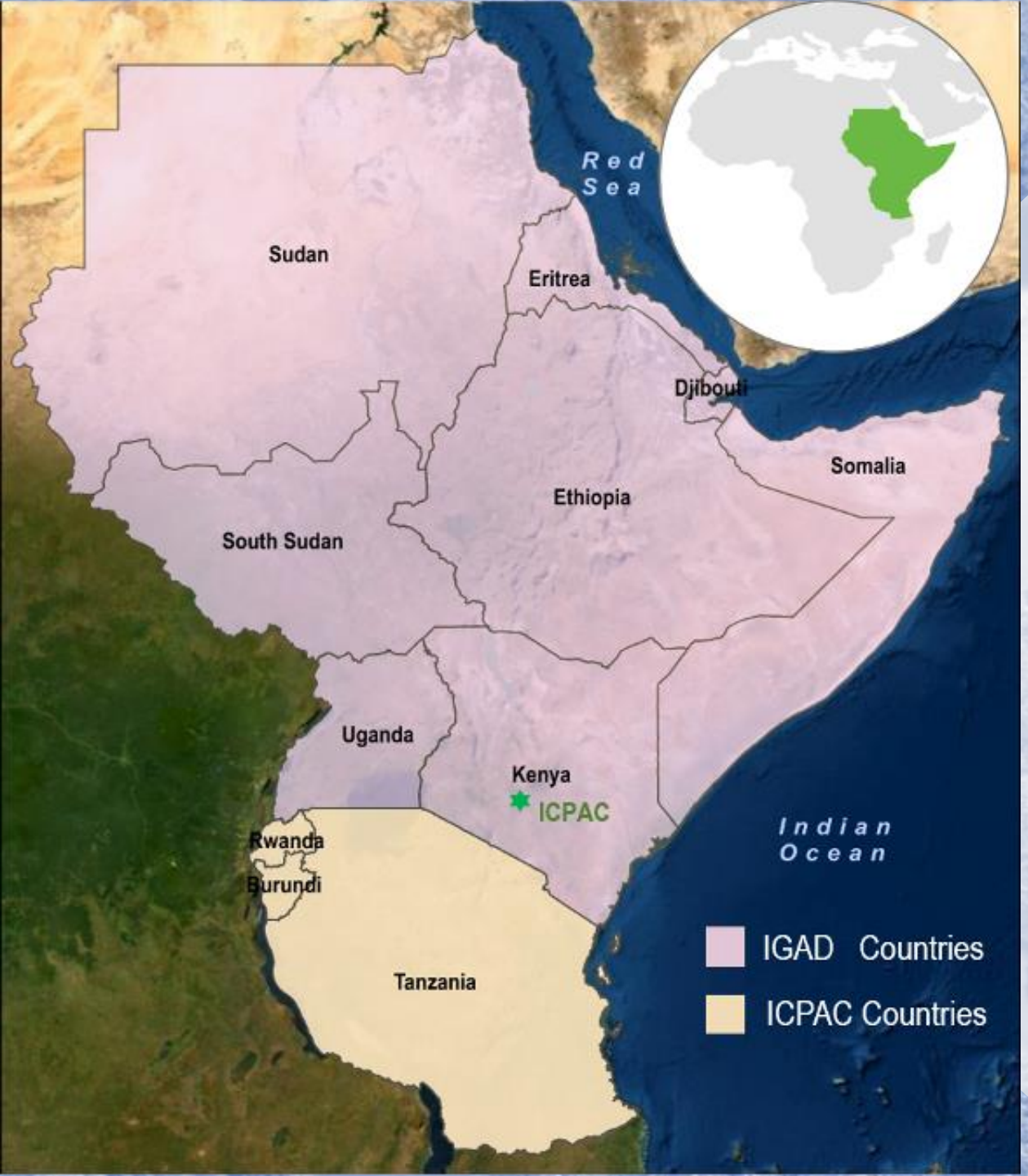
SWALIM FAO

BRICS / Norwegian Refugee Council

IGAD CLIMATE PREDICTION AND APPLICATIONS CENTRE (ICPAC)

11/17/2025

Jully Ouma - TL:EWS



- Established in **1989** as DMC, in Nairobi.
- Adopted by IGAD in **2007** as IGAD Climate Prediction and Application Centre.

WMO
World Meteorological Organization

UNFCCC

RCC in May 2017

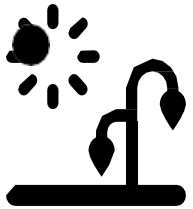
Observer status

AUDA - NEPAD
AFRICAN UNION DEVELOPMENT AGENCY

Central and East Africa - Centre of Excellence

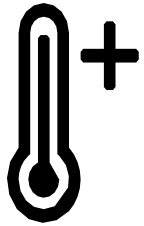
ICPAC units

Climate Diagnostic and Prediction

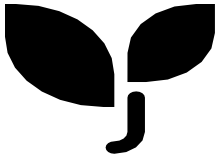


Disaster Risk Management

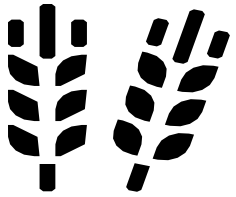
Climate Applications



Climate Change



Data Management, Remote Sensing and Geospatial



The IGAD Food Security, Nutrition and resilience analysis Hub, IFRAH

ICPAC

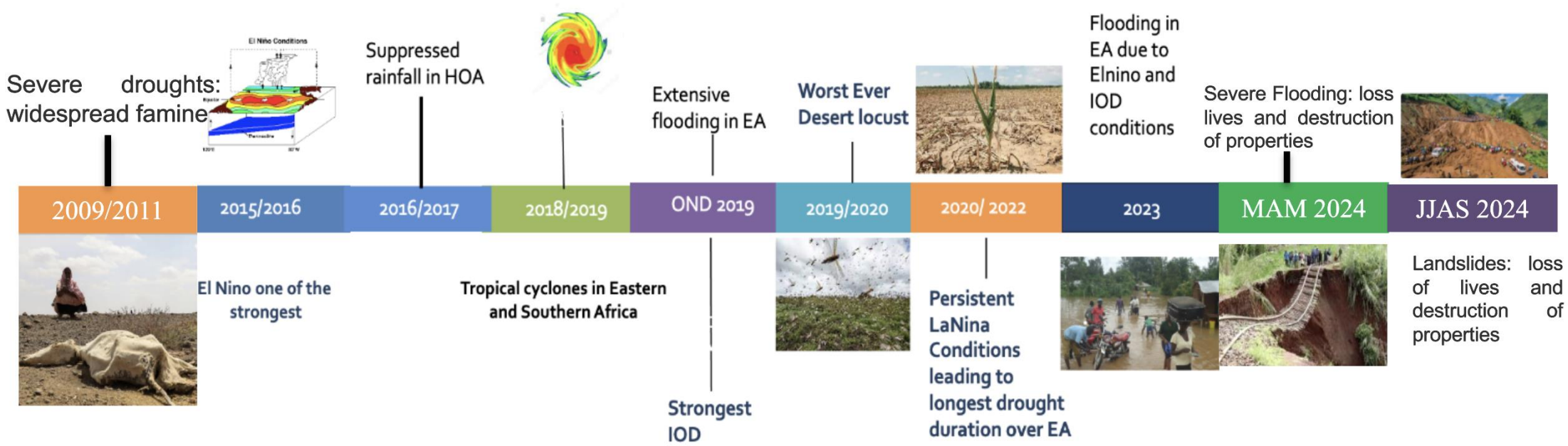
ICPAC SERVICES

ICPAC

- Climate Forecasting
- Disaster Risk Management
- Water Resources
- Agriculture and Food Security
- Environmental Monitoring
- Capacity Development
- Climate Change
- Climate Information Dissemination

MISSION: Foster climate services and knowledge to enhance community resilience in the region

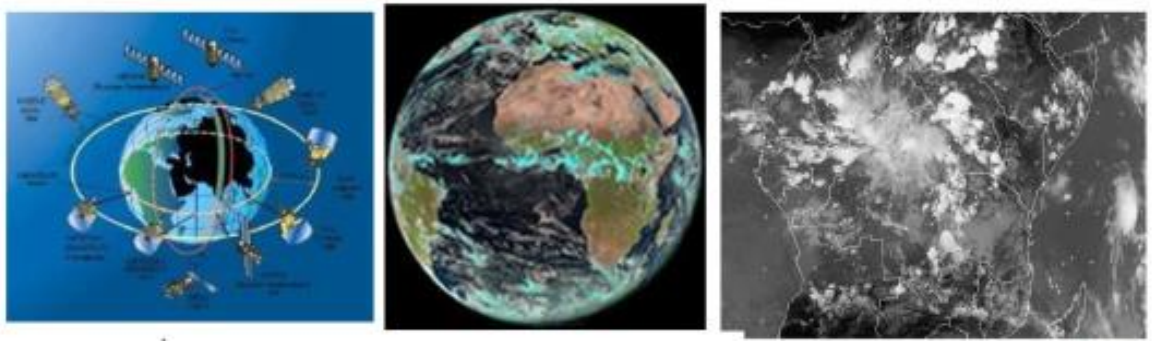
RECENT INTERPLAY OF CLIMATE RISKS OVER IGAD REGION

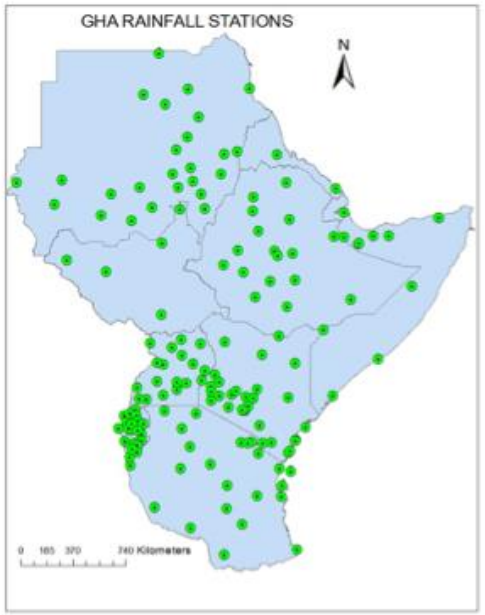


ICPAC

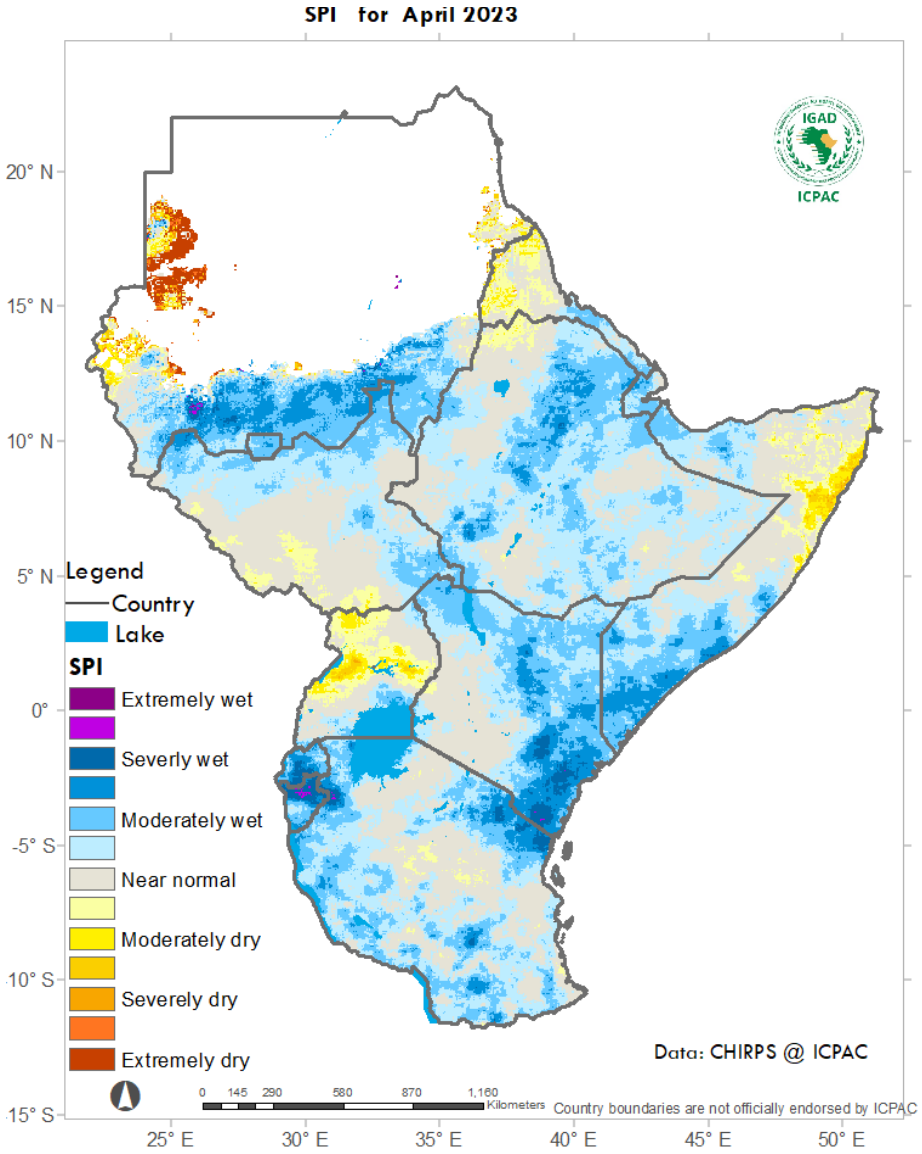
DATA SERVICES: FROM STATION DATA TO GRIDDED DATASETS

- Produce blended and gridded high resolution regional and national climate data sets using various tools





ICPAC receives data from 150 active weather stations of NMHSs as well as PUMA and RARS (satellite ground receiving stations)



IGAD
ICPAC

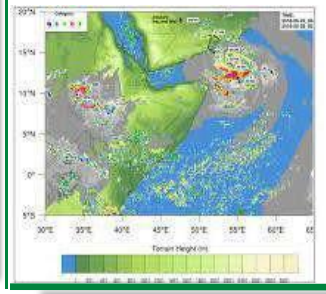
SEAMLESS EARLY WARNING INFORMATION

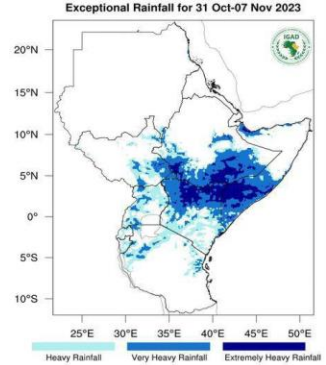
Informed Planning

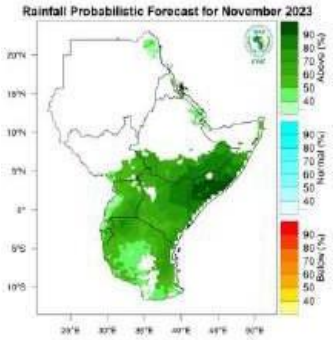
Strategic planning and scenario building

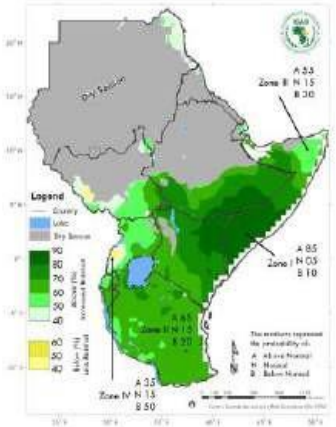
Preparedness planning

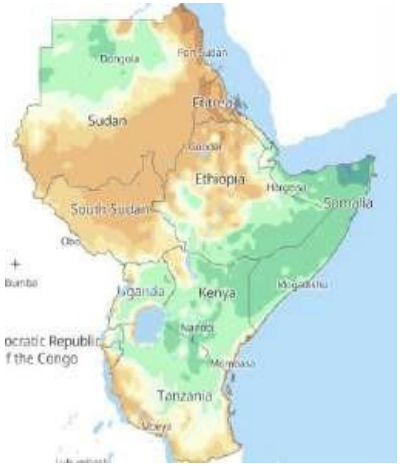
Response and relief









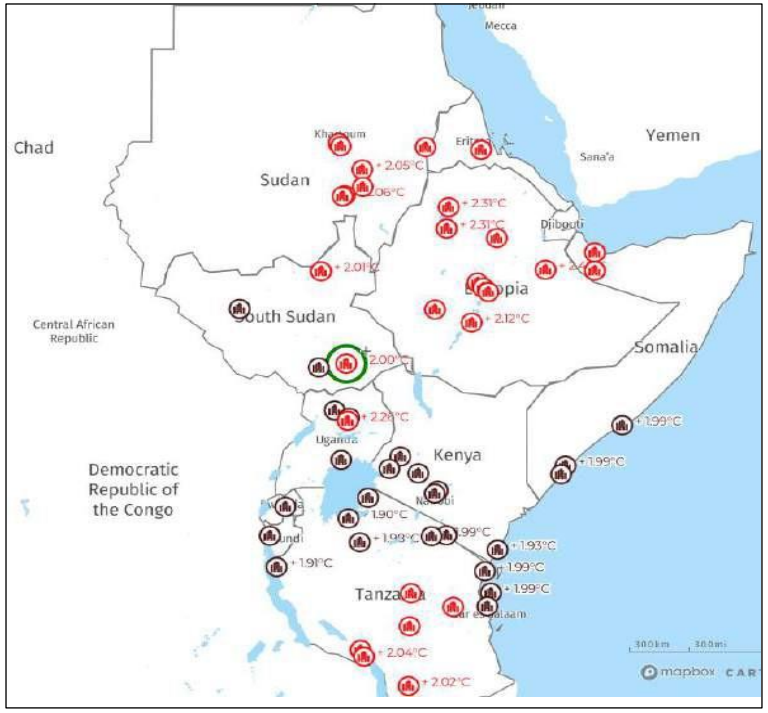


Few hours to daily | Weekly | Monthly | Seasonal | Climate change

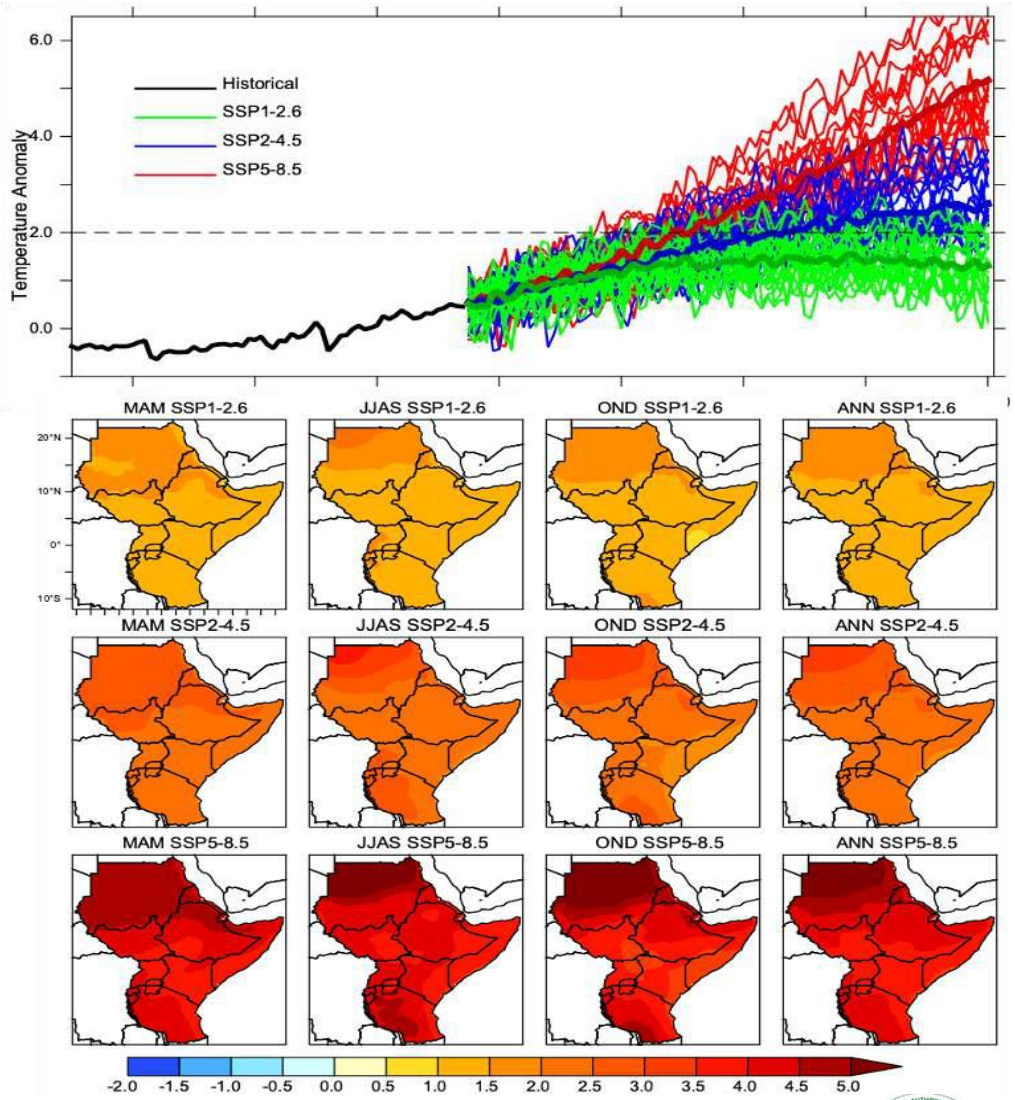
Timescales

ICPAC

CLIMATE CHANGE: THE IGAD REGION IS WARMING



- Eastern Africa has warmed beyond the Paris Agreement agreed value 1.5 and even beyond the 2.0 degree
- Projections shows further warming in the future
- Adaptation and mitigation strategies are key: IGAD climate Change strategy



IGAD
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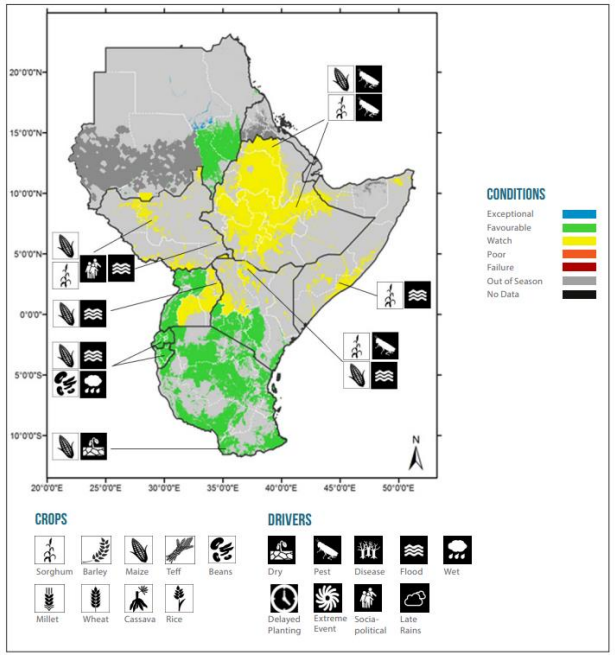
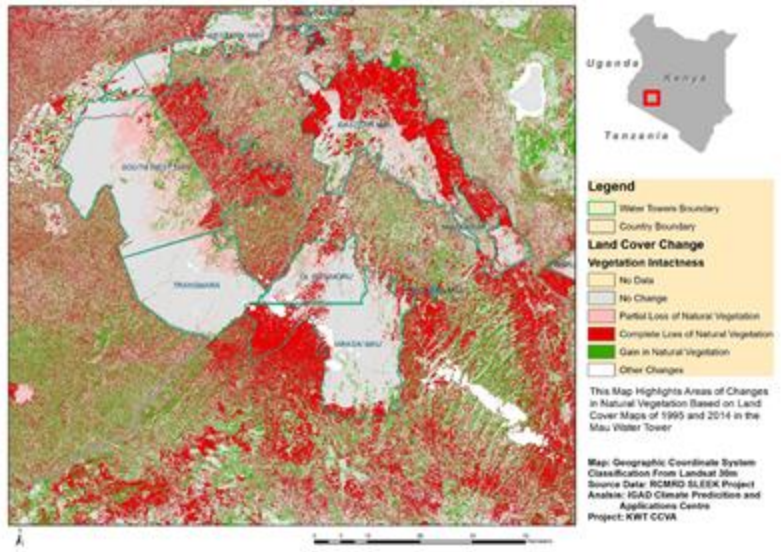
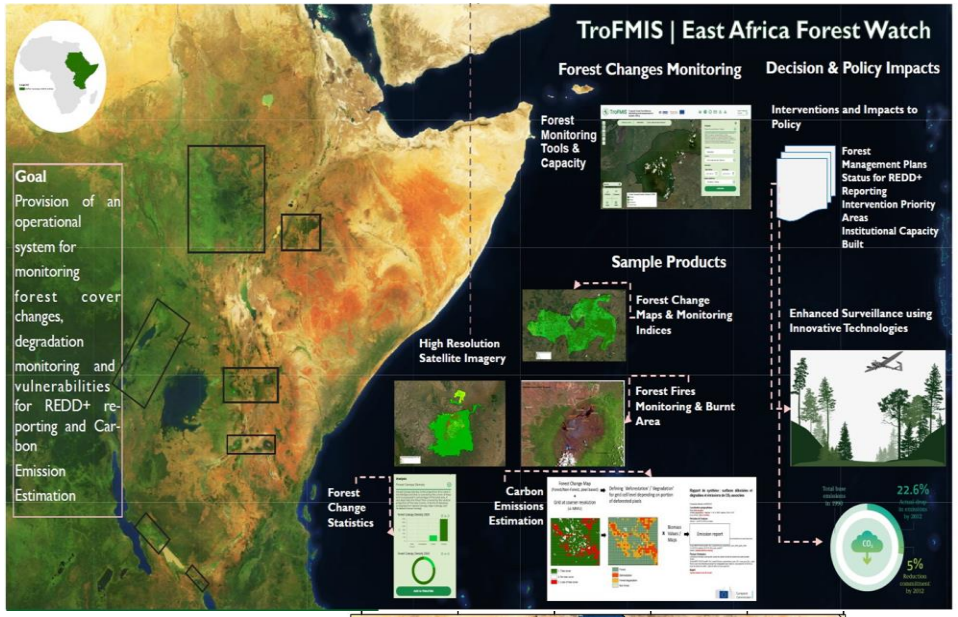
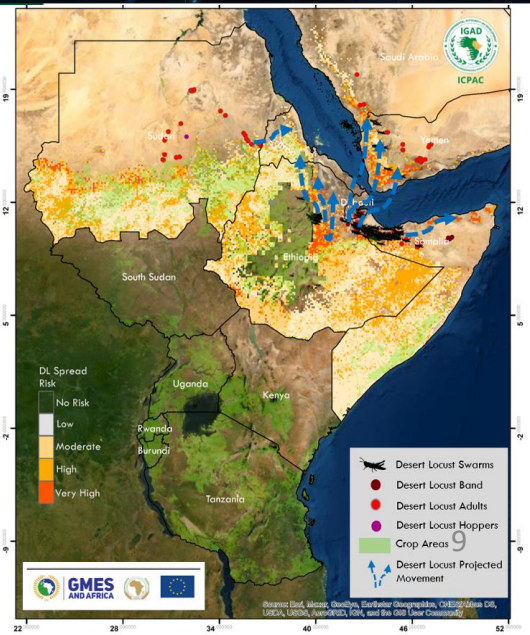
MONITORING OF CROPS, FORESTS AND PESTS



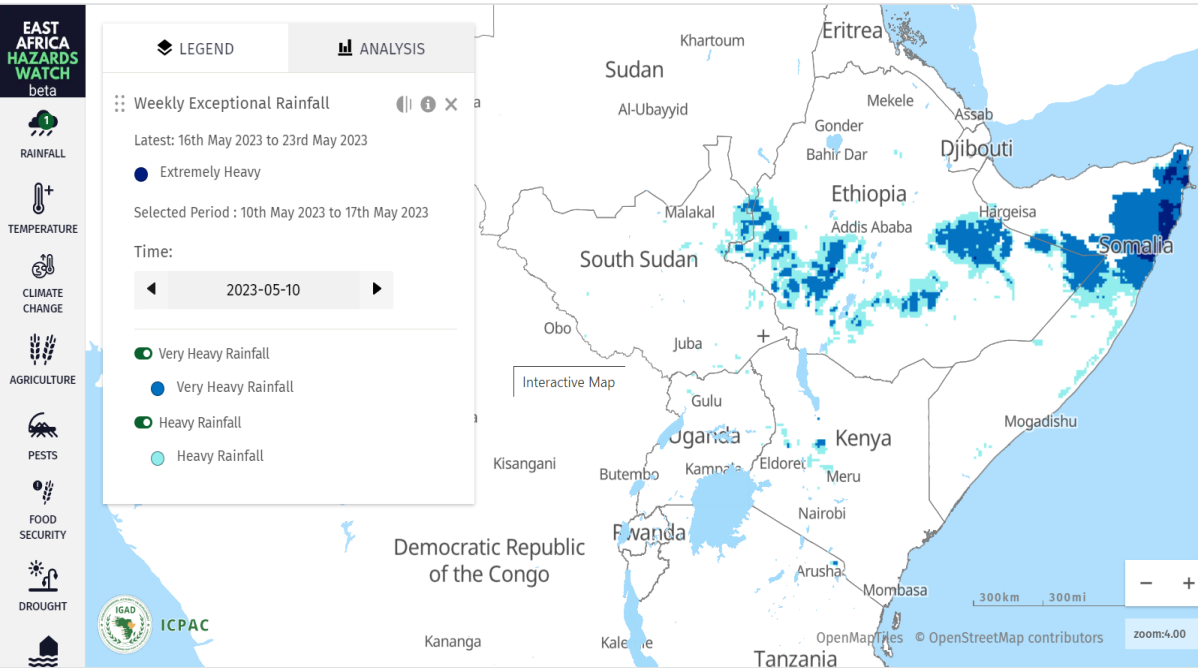




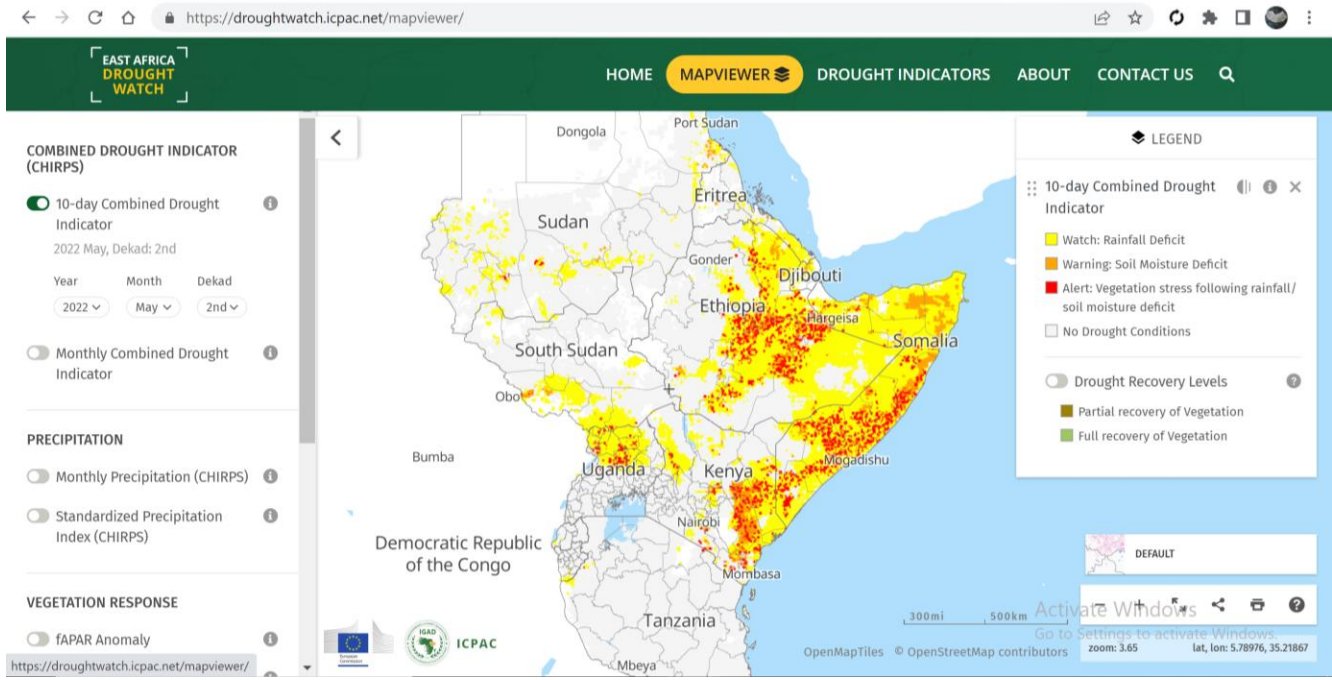
- Crop monitor analyses various crops conditions at different times of the cropping season
- Protected forests monitoring for carbon emission estimation
- Desert locust prediction helps in planning on resources allocation for control measures



East Africa Hazards watch



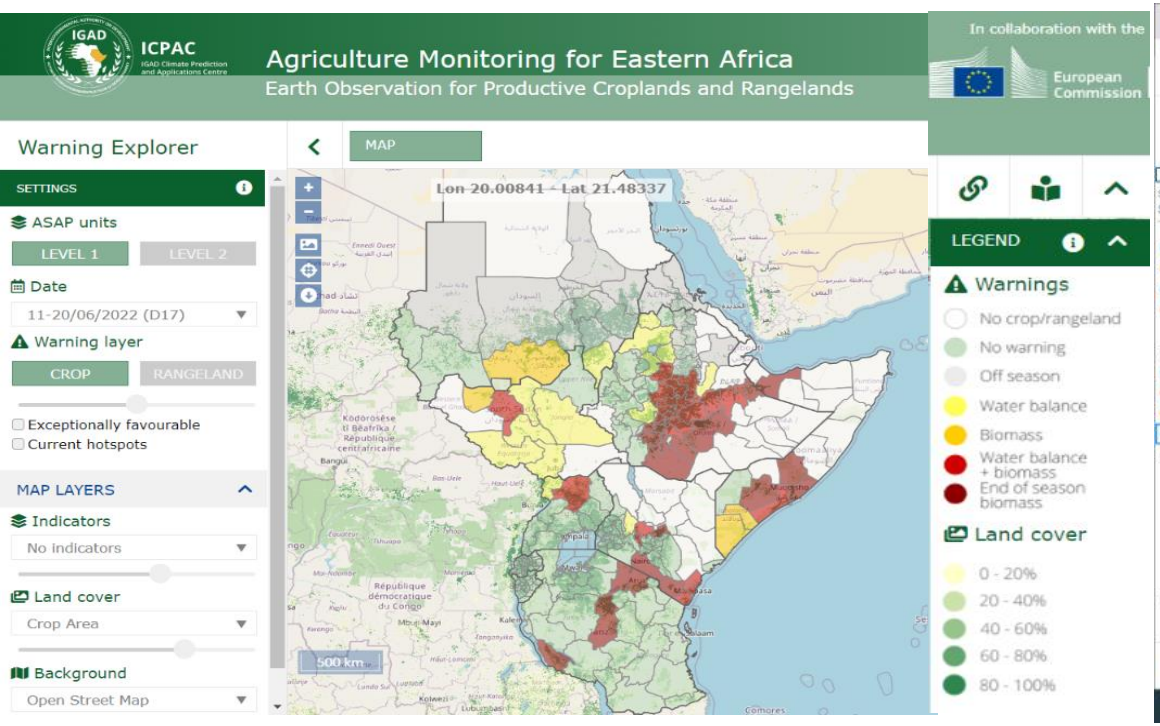
East Africa Drought watch

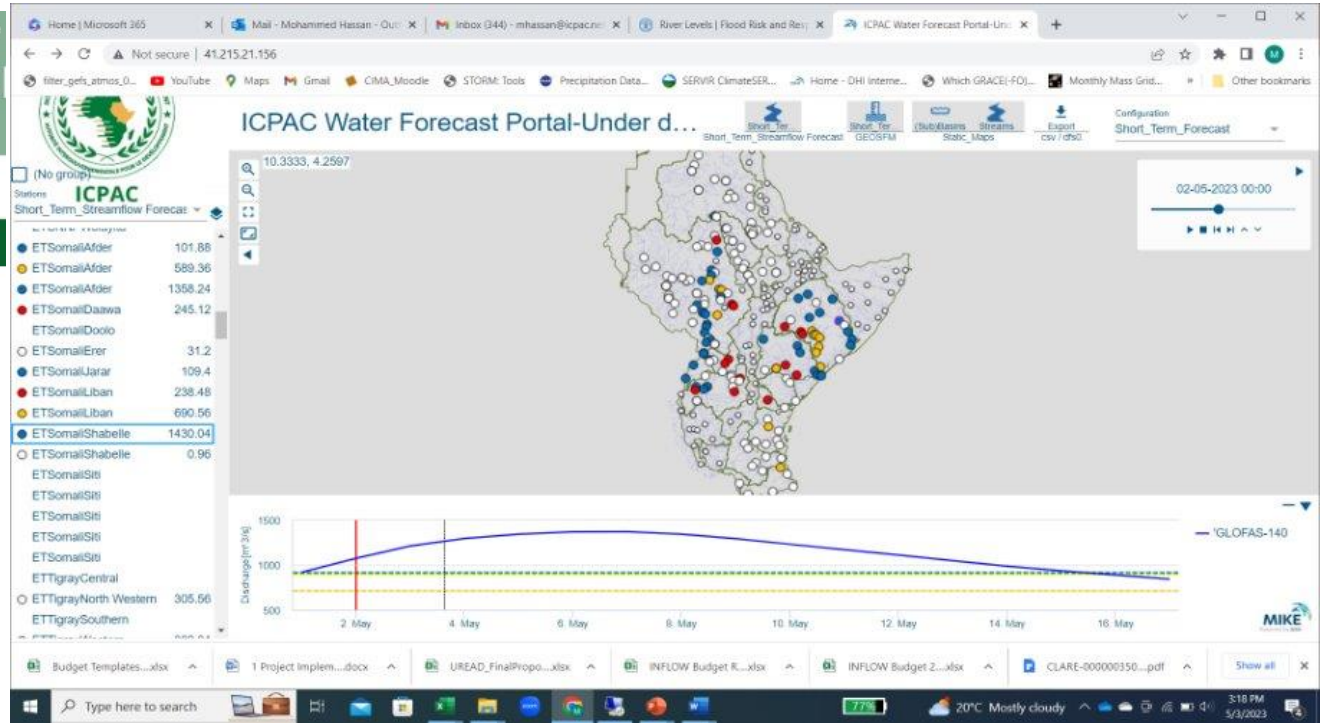


IGAD
ICPAC

East Africa Agriculture watch

Water Portal



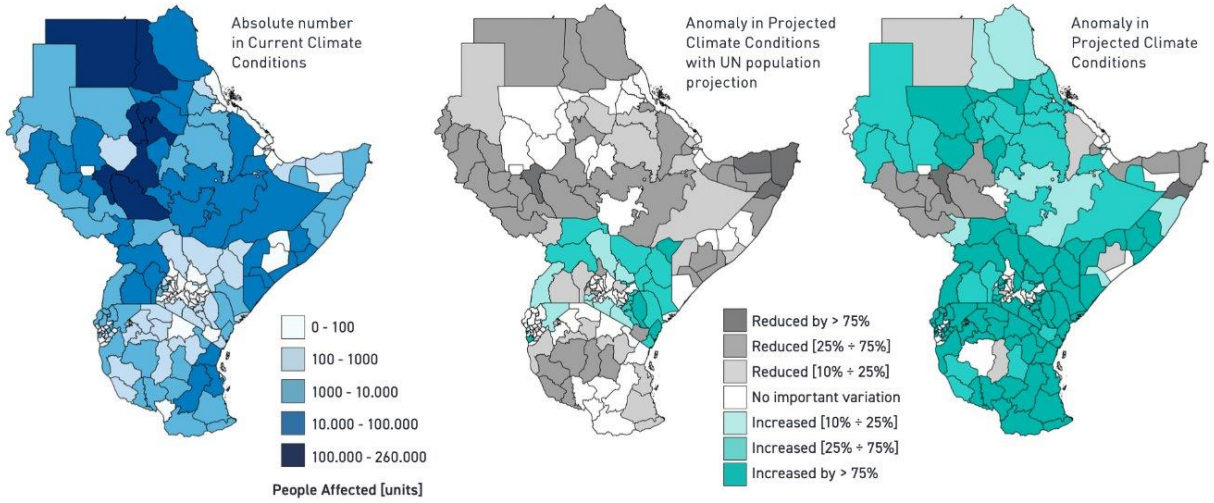


ICPAC

REGIONAL RISK ASSESSMENT AND RISK PROFILES

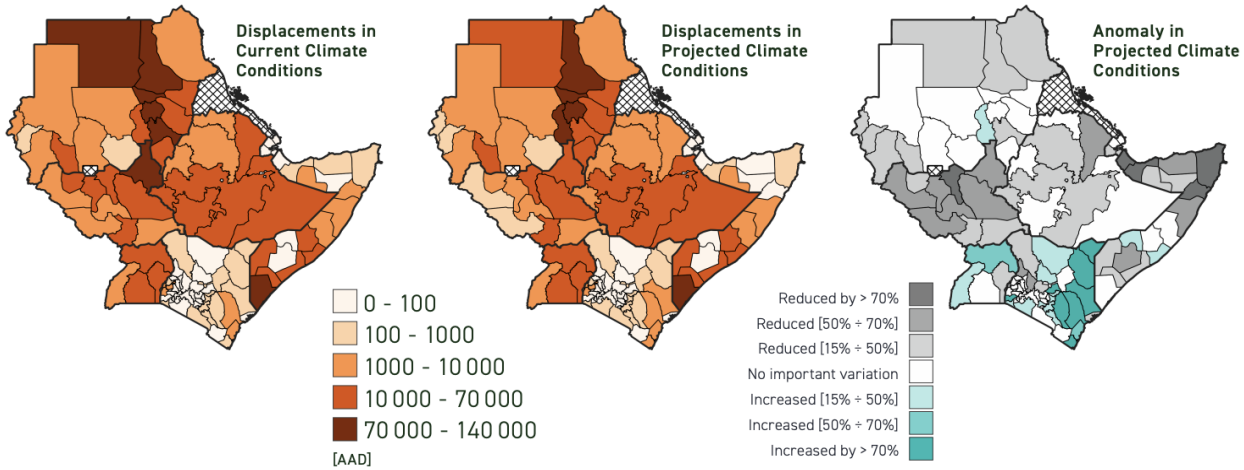
Flood Risk Profile

Annual Average Number of People Affected by flood events at province or county level - Figure 2



Displacement /migration modeling

ANNUAL AVERAGE DISPLACEMENT TRIGGERED BY FLOOD EVENTS AT PROVINCE OR COUNTY LEVEL



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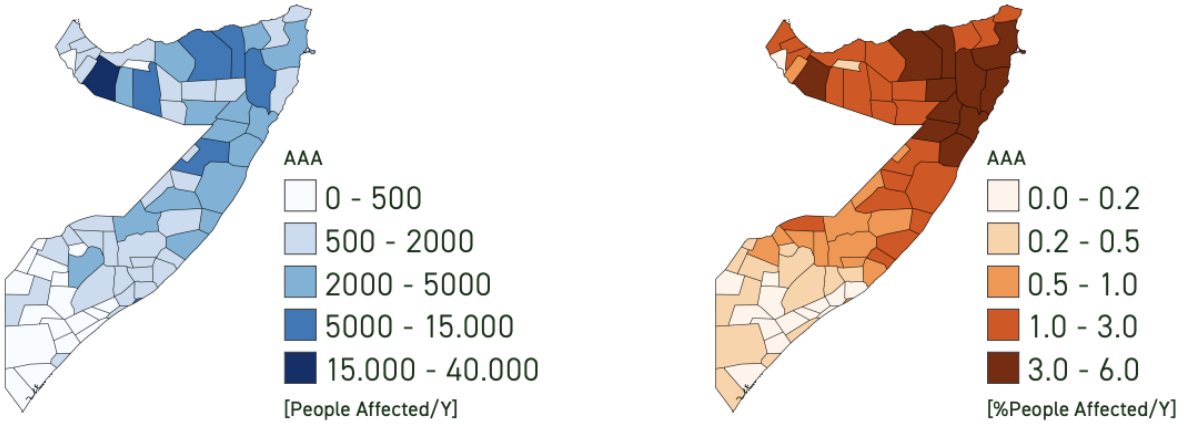
Cyclone Impacts in Somalia

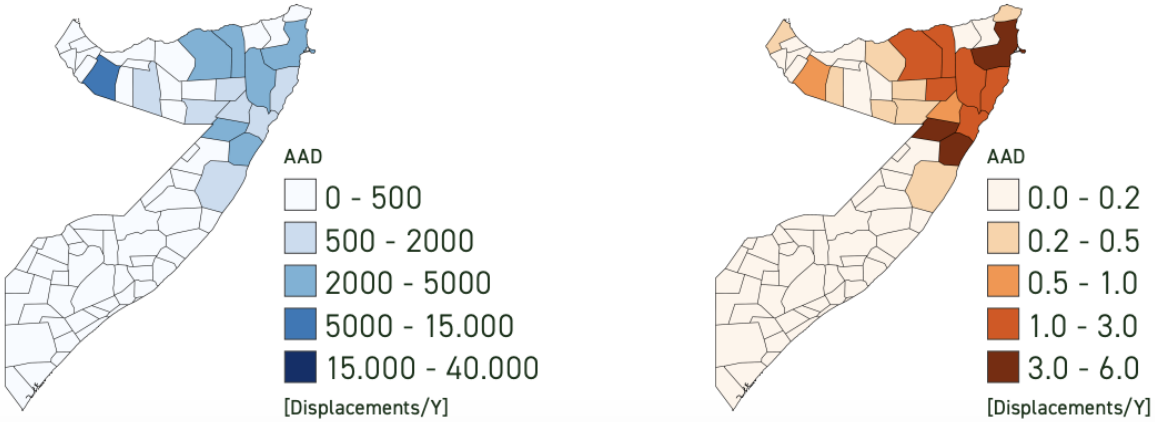
(Loss and Damage)

ANNUAL AVERAGE NUMBER OF PEOPLE AFFECTED BY CYCLONE EVENTS AT DISTRICT LEVEL (ON THE LEFT) AND THE CORRESPONDING PERCENTAGE IN RESPECT TO THE TOTAL POPULATION AT DISTRICT LEVEL (ON THE RIGHT)



The total number of people potentially affected by cyclone events in Somalia is around 180,000, corresponding to 1% of the total country population: in some districts in the northeastern part of the country this value exceeds 5%.

ANNUAL AVERAGE NUMBER OF PEOPLE POTENTIALLY DISPLACED BY CYCLONE EVENTS AT DISTRICT LEVEL (ON THE LEFT) AND THE CORRESPONDING PERCENTAGE IN RESPECT TO THE TOTAL POPULATION AT DISTRICT LEVEL (ON THE RIGHT)



DISASTER OPERATIONS CENTER

Situation Room

ICPAC

01 Monitor major hazards and issue early warning information for the region

02 Coordination with national focal institutions on early action.

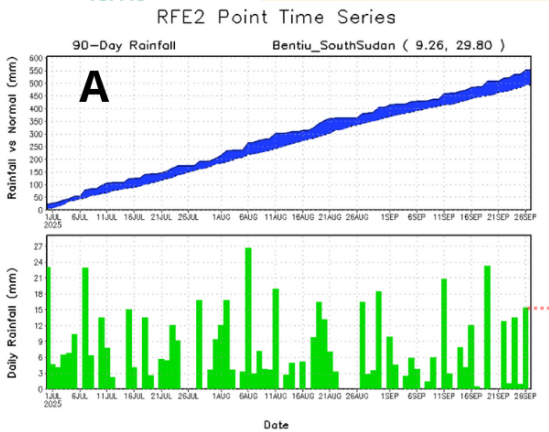
03 Rapid mapping of affected areas and impacts of disasters

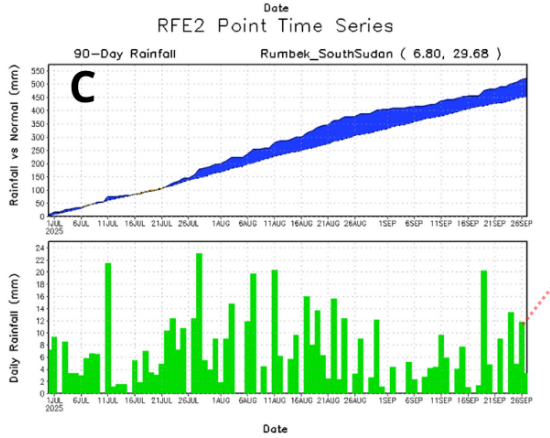
04 Strengthen Capacity to anticipate risk & Support AU Early warning Situation Room

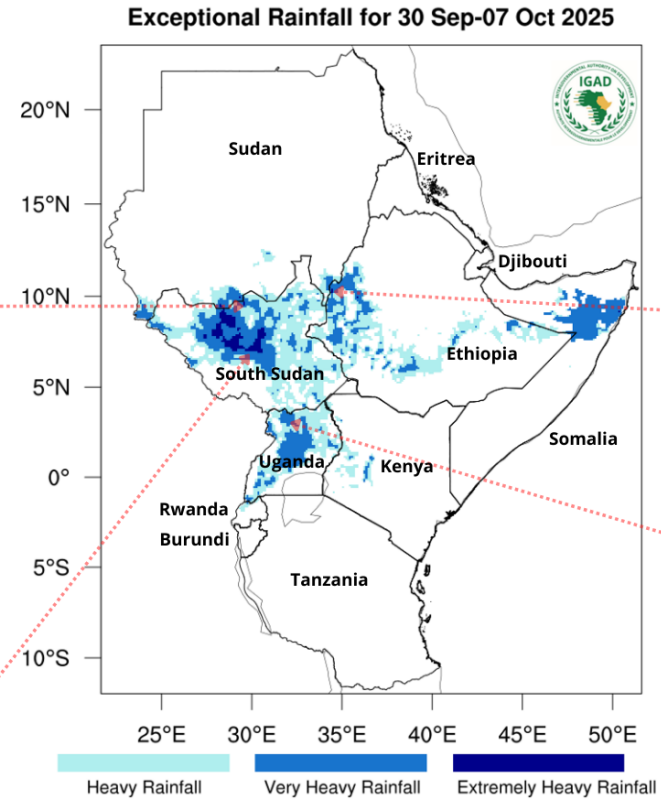
Disaster Operations Centre - Floods Update

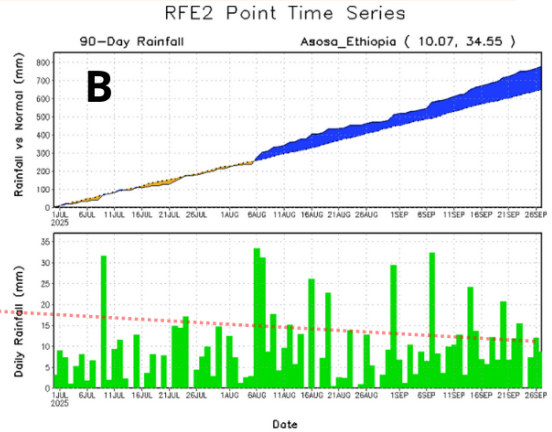
IGAD Multi-Hazard Early Warning Early Action - Situation-Room

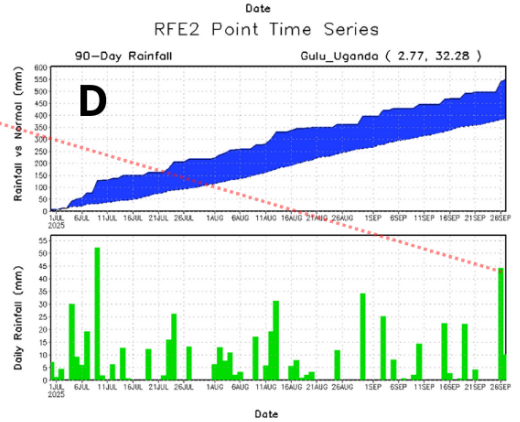
Issue No.103 September 29, 2025











Situation Overview

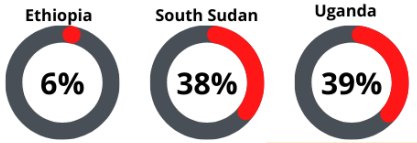
- Some pockets in western Ethiopia, central to north-central South Sudan, and northern Uganda received rainfall in the past week, with daily accumulation in Bentiu, South Sudan, reaching 16mm (A), Asosa, Ethiopia, at 13mm (B), Rumbek, South Sudan at 12mm (C), and Gulu, Uganda, at 44mm (D).

Advisory for the next 7 days

- In the coming week, very heavy rainfall is expected over western Ethiopia, central to north-central South Sudan, and central to north-central Uganda.
- Flooding incidences are expected over the flood prone areas in north-central Uganda, central to north-central parts of South Sudan, and pockets in western Ethiopia.
- Communities in high-risk areas are advised to exercise caution during this period.

Estimated population exposed by countries:

In percentage under extremely/very heavy rainfall area

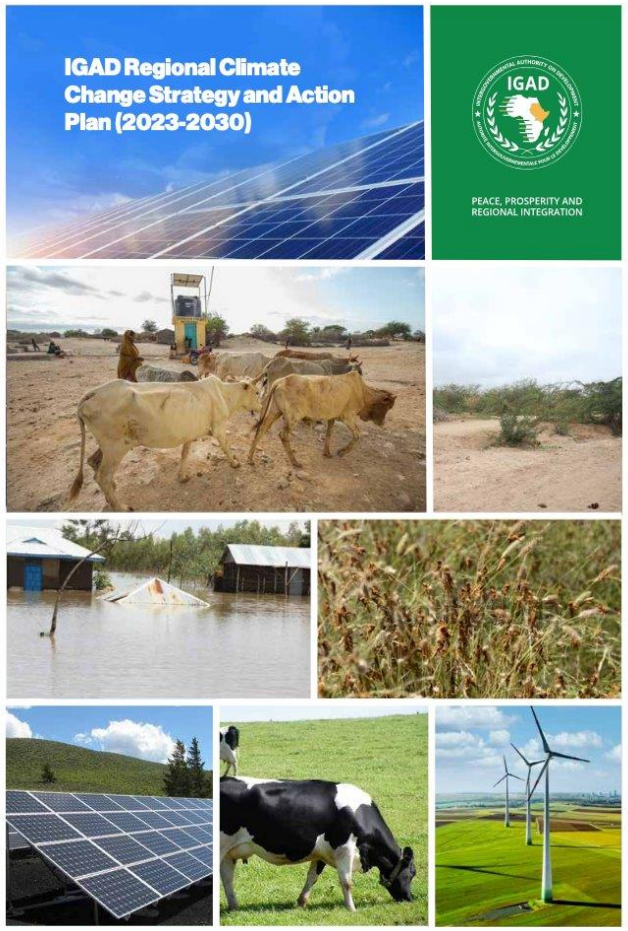


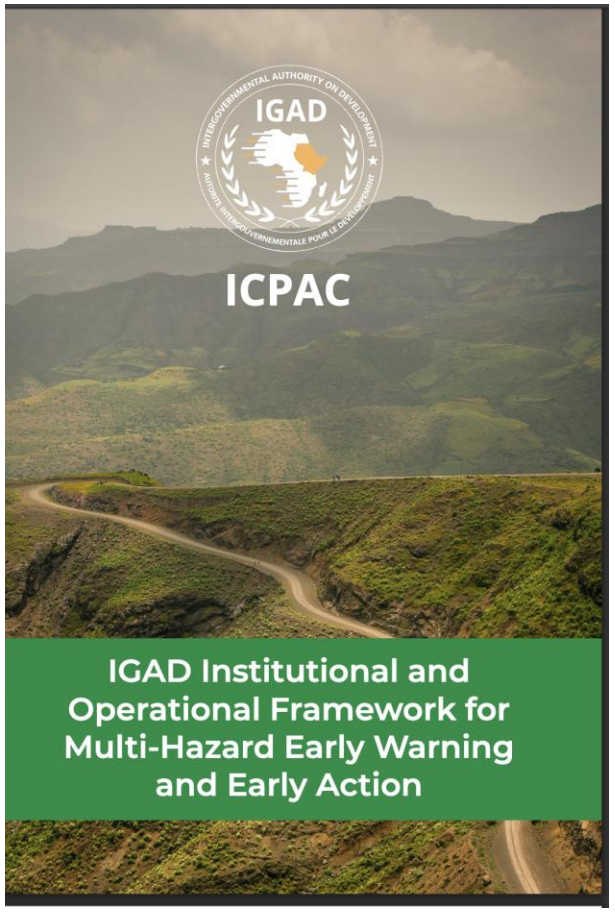
East Africa Hazards Watch: https://eahazardswatch.icpac.net

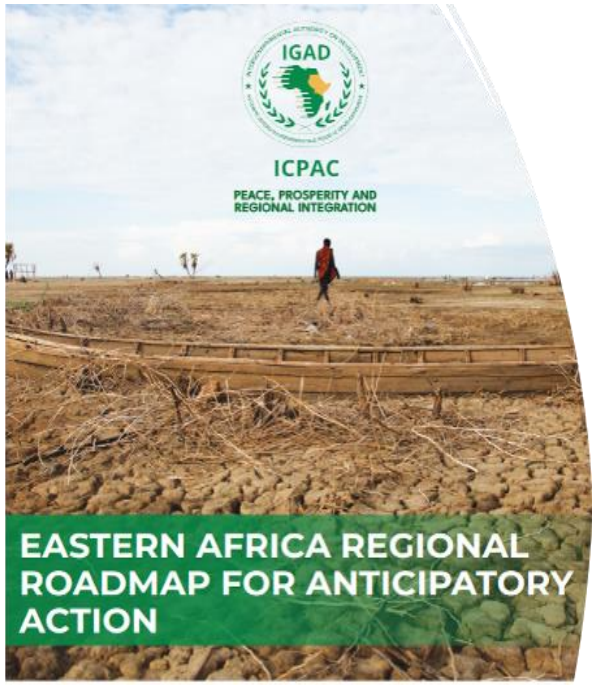
Data/Infor Sources: ICPAC/IGAD-Member States/NOAA-RFE/Verisk

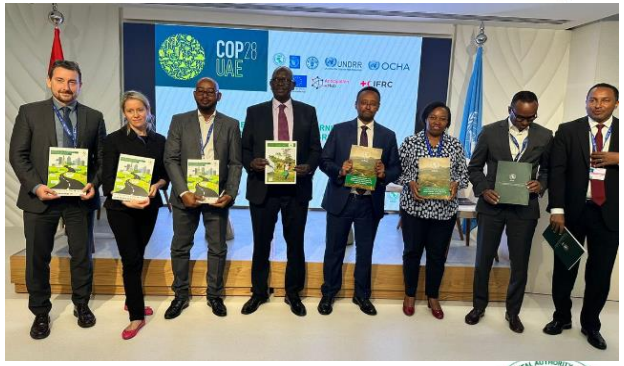
Contact: disaster-risk-management@igad.int

ICPAC REGIONAL STRATEGIES AND FRAMEWORKS









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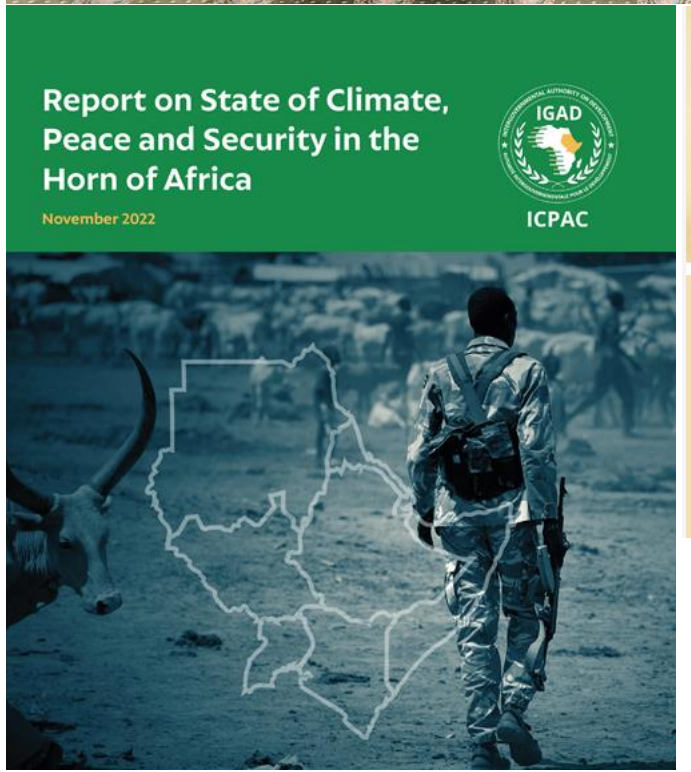
IGAD CLIMATE SECURITY CORDINATION MECHANISM

- Climate Security pathways agreed on by technical experts from member states in July 2022;
- Mechanism created by IGAD Sector Ministers at COP 27 in November 2022;
- Endorsed by IGAD Council of Ministers in Nov 2022;
- Endorsed by IGAD Heads of States in June 2023;



Addressing Climate Change, Peace and Security in the Horn of Africa

Climate change, population growth and economic development are some of the major forces driving the need for improved security in the Greater Horn of Africa. The region is vulnerable to natural hazard-induced disasters such as droughts and floods. Increasing urbanization and industrialization have led to greater demand for food, water and power. In addition, increased migration from rural areas to cities will put an added strain on public services such as health care and education. Addressing these challenges is critical to ensuring the long-term stability of the region. This policy brief summarizes the climate, environmental and related risks and their possible interlinkages to the peace and security sector based on an accompanying background paper and a regional

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USER ENGAGEMNT: REGIONAL TO COMMUNITY LEVEL

GHACOF → NCOF → PSP → PICSA

ETHIOPIA

Disaster Risk Management

The country is expected to experience drought condition affecting the central and northern parts of the country. However, the southern and eastern parts are expected to experience river floods and flash flood with the possibility of wet spells between 4 to 6 days.

Advisory
- Destock livestock early.
- Encourage Ministry of Agriculture and Livestock to preserve animal feed.
- Implement drought and flood contingency plan coordinated by Ethiopian Disaster Risk Management Commission (EDRMC).
- Clear and improve major drainage systems to be led by the ministry of water.

Agriculture and Food Security

Expected moisture condition favours crop growth in South-west of Somali region, Southern Oromia and south Ethiopia. Generally good conditions for land preparation and sowing of irrigated farms in the central and northern parts where it is dry climatologically. Wet conditions in the south favours breeding of Desert locust and other pests. Likelihood of flash flooding in some part of southern Ethiopia which might impact on croplands.

Advisory
- Provide agricultural inputs on time to OND benefiting areas of southern and eastern Ethiopia.
- Issue early warning alerts and heightened measure against possible desert locust invasion.
- Undertake proper post-harvest management for the main season crop (JJAS).

Water and Energy

Adequate water availability in areas where the OND is the rainy season. Risk of flooding in downstream areas.

Advisory
- Raise awareness on flood risk areas in time.
- Continuously monitor dam levels.

Livestock

Regeneration of pasture, availability of water, reduce livestock mobility in search of water and pasture. Food security and good nutrition. Reduced pneumonias due to predicted warmer temperatures. Increased livestock productivity (meat, milk, hides & skins). Expected stable prices or improved due to exports and good animal body condition. Favorable for vaccination and water harvesting.

Advisory
- Enhance disease surveillance especially for RVF.
- Enhance production and conservation of fodder including benefits from JJAS beneficiary areas.
- Enhance water harvesting.
- Facilitate community awareness about expected enhanced rains either to relocate due to floods, plant fodder, present animals for vaccination, water harvesting etc.
- Increase control efforts towards desert locust.

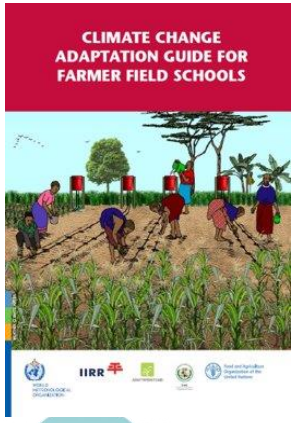
Linking Regional to Community Level

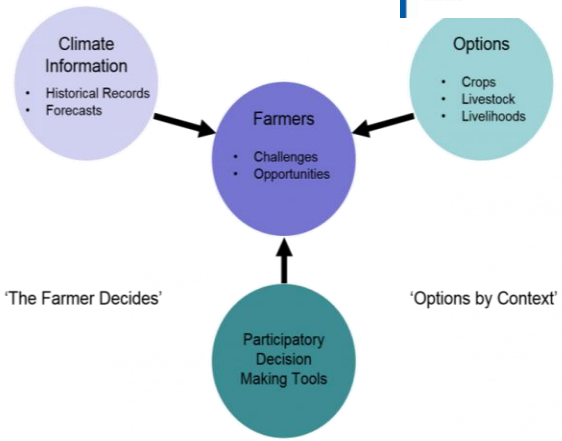
GHACOF → NCOF → PSP → PICSA

NCOFs are held at national level and a summary for decision makers produced for policy makers

Stakeholders generating agricultural advisories based on seasonal forecast during a PSP event

Small holder farmer women trained on PICSA





Seasonal sectoral advisories translated to local language

CLIMATE CHANGE ADAPTATION INITIATIVES (GARISSA-KENYA)

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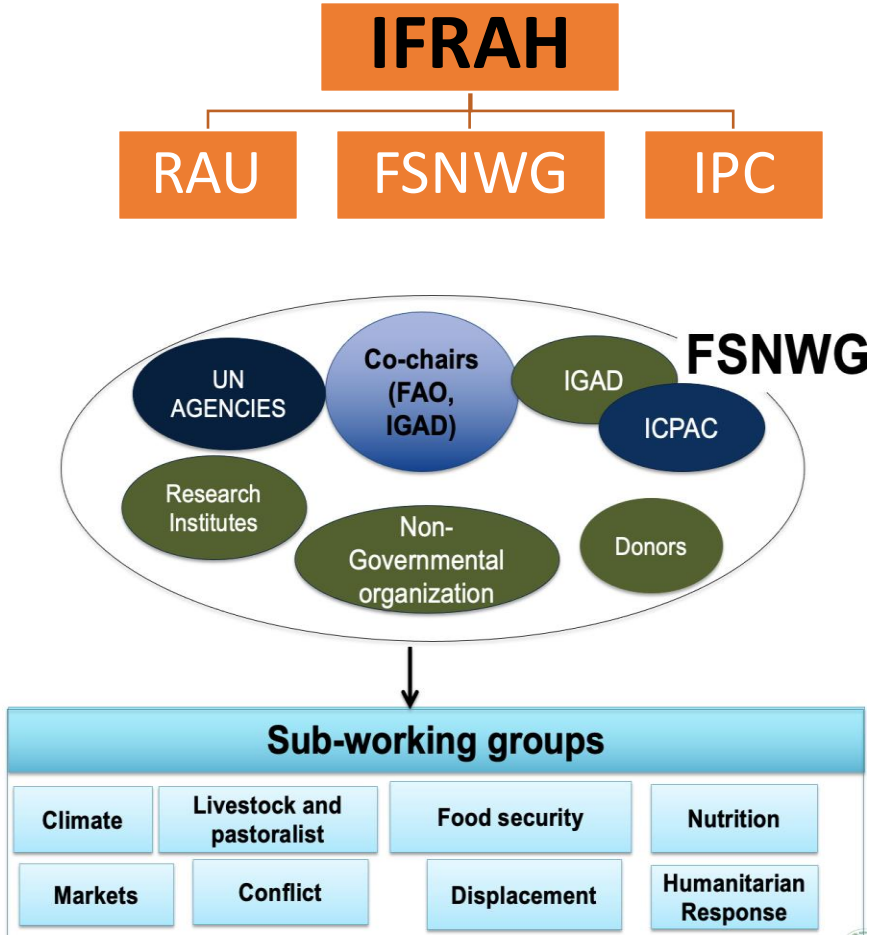
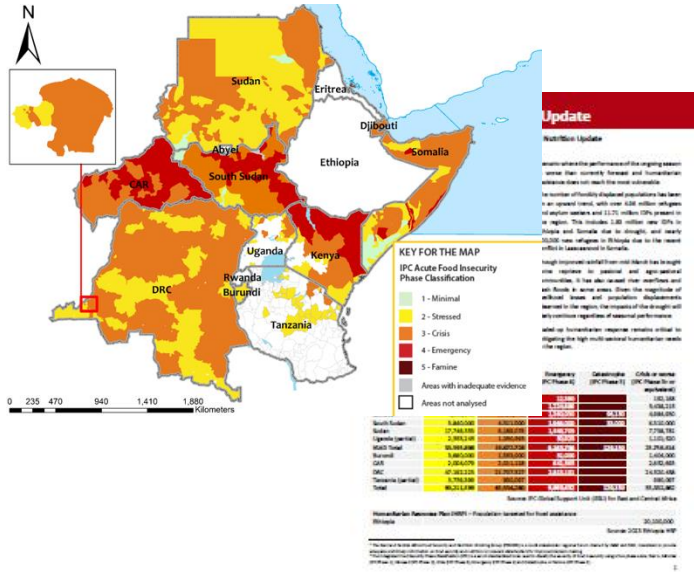
IGAD Food security, nutrition & resilience analysis hub





CAPACITY BUILDING TRAININGS FOR MEMBER STATES

Key Areas of Capacity Building: climate modelling and prediction, co-production, climate change adaptation, risk assessment, Early warning systems, anticipatory action, DRR, communication, ..etc.

Some selected high impacts Publications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Original research article

Increasing the prospective capacity of global crop and rangeland monitoring with phenology tailored seasonal precipitation forecasts

Michele Meroni [a 1], Petar Vojnović [b 1], Matteo Zampieri [c d], Stefano Materia [e f], Felix Rembold [c], Oliver Kipkogei [g], Andrea Toreti [c]

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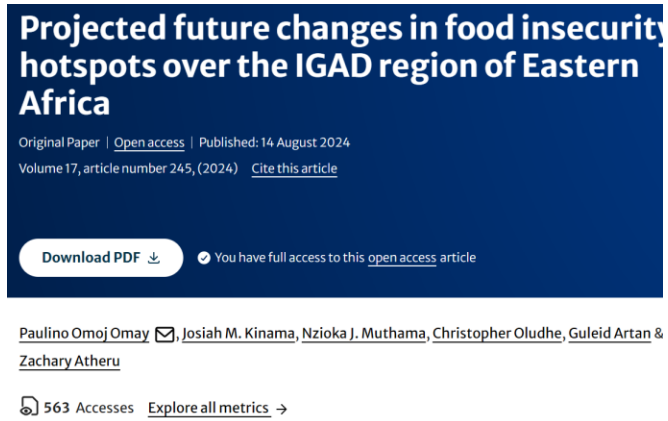
Abstract

Droughts are more and more often a limiting factor to agricultural production and can have severe negative effects on food security in


Projected future changes in food insecurity hotspots over the IGAD region of Eastern Africa

Original Paper | Open access | Published: 14 August 2024

Volume 17, article number 245, (2024) Cite this article

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Paulino Omoj Omay, Josiah M. Kinama, Nzioka J. Muthama, Christopher Oludhe, Guleid Artan & Zachary Atheru

563 Accesses Explore all metrics


Open Access Technical Note

New Functionalities and Regional/National Use Cases of the Anomaly Hotspots of Agricultural Production (ASAP) Platform

by Felix Rembold [1,*], Michele Meroni [1], Viola Otieno [2], Oliver Kipkogei [2], Kenneth Mwangi [2], João Maria de Sousa Afonso [3], Isidro Metódio Tuleni Johannes Ihadua [3], Amílcar Ernesto A. José [3], Louis Evence Zoungrana [4], Amjed Hadj Taieb [4], Ferdinando Urbano [1], Maria Dimou [1], Hervé Kerdiles [1], Petar Vojnovic [1], Matteo Zampieri [1,5] and Andrea Toreti [1]

[1] Joint Research Centre (JRC), European Commission, Via E. Fermi 2749, I-21027 Ispra, VA, Italy
[2] Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC), Nairobi P.O. Box 10304-00100, Kenya
[3] Instituto Nacional de Meteorologia e Geofísica de Angola (INAMET), Rua 21 de Janeiro, Rotunda do Gamek à Direita, S/N-RC, Luanda 1323, Angola
[4] GIS and Remote Sensing Unit, Observatoire du Sahara et du Sahel (OSS), P.O. Box 31, Boulevard du Leader Yasser Arafat, Tunis 1080, Tunisia
[5] Department of Physical Science and Engineering, King Abdullah University of Science and Technology (KAUST), Thuwal 23955, Saudi Arabia
* Author to whom correspondence should be addressed.

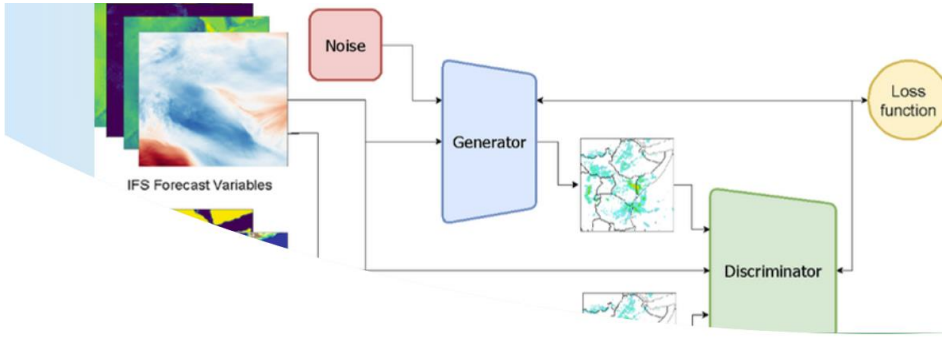
Remote Sens. **2023**, *15*(17), 4284; https://doi.org/10.3390/rs15174284

Submission received: 26 June 2023 / Revised: 21 July 2023 / Accepted: 5 August 2023 / Published: 31 August 2023

TITLE	AUTHORS	JOURNAL
Increasing the prospective capacity of global crop and rangeland monitoring with phenology tailored seasonal precipitation forecasts.	Meroni, M., et al.	Climate Services https://doi.org/10.1016/j.cliser.2023.100434
Atmospheric and oceanic conditions associated with early and late onset for Eastern Africa short rains.	Gudoshava, M. et al.	International Journal of Climatology **https://doi.org/10.1002/joc.7627**
Forage Monitoring and Prediction Model for Early Warning Application over the East of Africa Region	Ouma, J et al.	Journal of Atmospheric Science Research https://doi.org/10.30564/jasr.v5i4.4809

Innovation

- **Machine Learning (ML)** and **Artificial Intelligence (AI)** to Strengthening Early Warning Systems for Anticipatory Action (SEWAA)



Explore Forecast Systems

This section provides quick visualization and exploration options for various weather and climate forecasting models.

cGAN 1000 Ensemble

State-of-the-art AI-based weather models to give more accurate and local predictions enabling particular countries and regions to better anticipate and prepare for extreme weather.

cGAN 50 Ensemble

State-of-the-art AI-based weather models to give more accurate and local predictions enabling particular countries and regions to better anticipate and prepare for extreme weather.

ECMWF IFS Ensemble Forecast

The IFS is a sophisticated data assimilation system combined with a global numerical model of the Earth system, supported by infrastructure to make forecast products available to Member and Co-operating States, and other users.

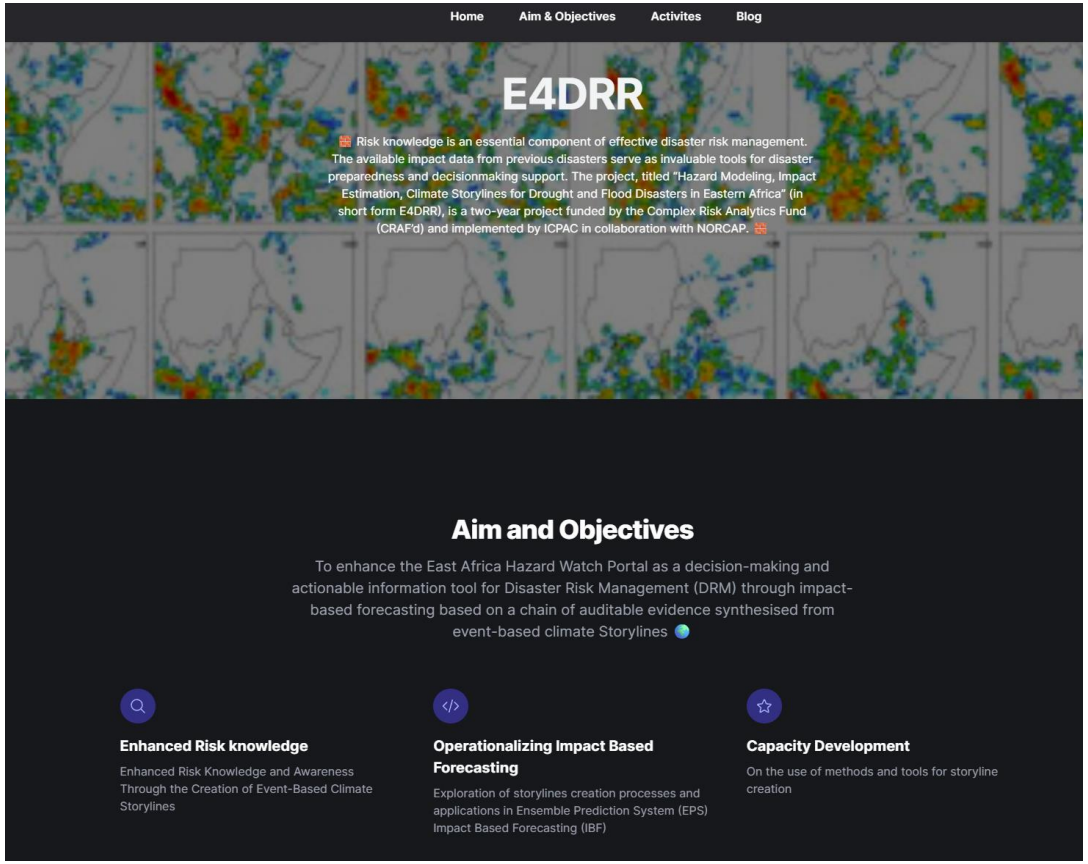
Global Ensemble Forecast System (GEFS)

A weather forecasting model developed by the National Centers for Environmental Prediction (NCEP). It generates 21 separate forecasts, or

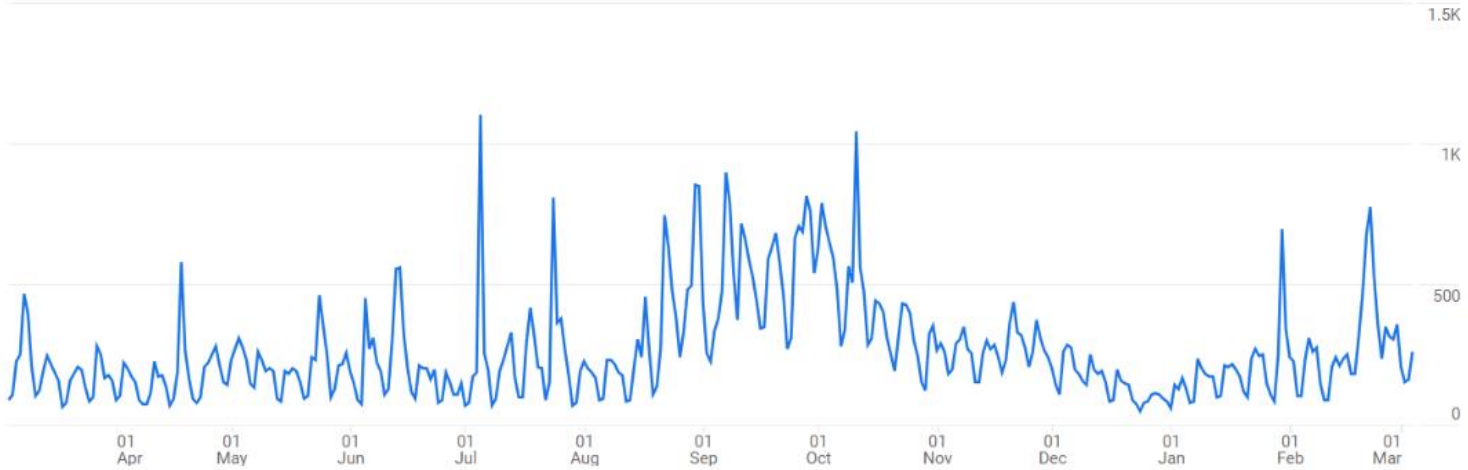
Embended External System

Forecast products sourced from partner systems and embended as-is.

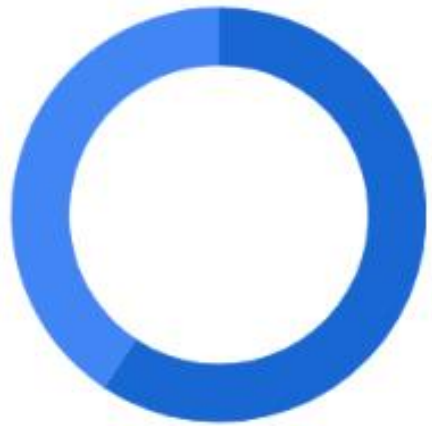
- **Machine Learning (ML)** and **Artificial Intelligence (AI)** to enhance Riks knowledge and Impact Based Forecasting



Users by Audience name over time



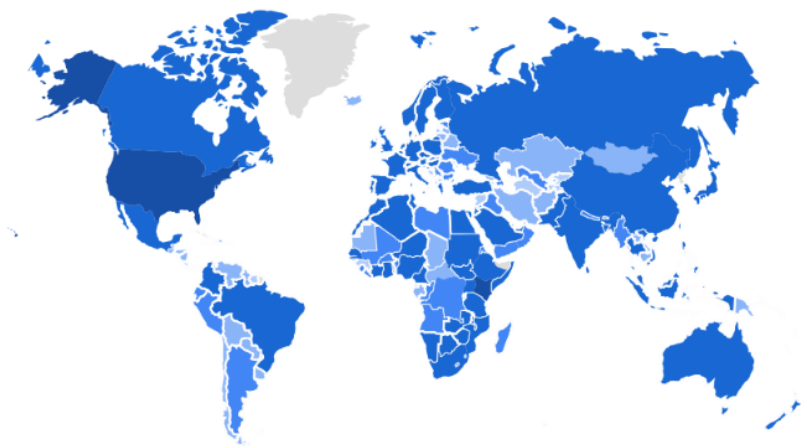
Users by Gender



MALE 59.3%

FEMALE 40.7%

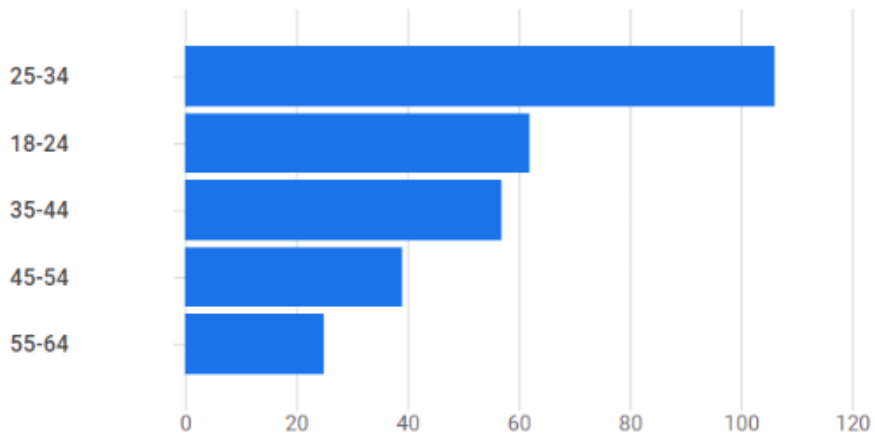
Users by Country



COUNTRY	USERS
Kenya	26K
United States	7K
Somalia	4.8K
United Kingdom	3.5K
Ethiopia	3.3K
Netherlands	3.3K
Uganda	2.9K

View countries →

Users by Age



~ 300 million people

husika

Multi-Channel On-Boarding

Web Platform

HUSIKA.ICPAC.NET

Android OS

iPhone/iPad

ICPAC

Thank you !

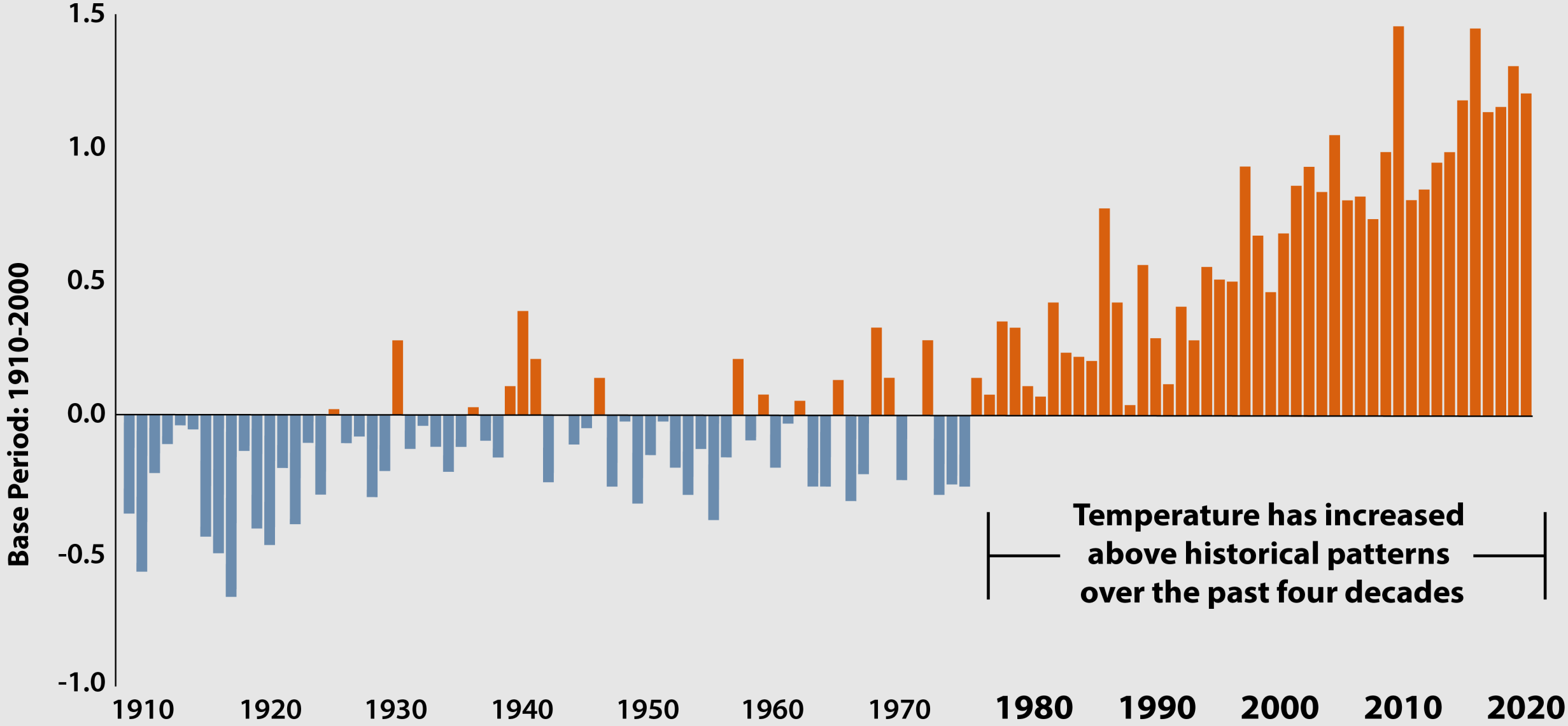
HUMAN MOBILITY IN THE CONTEXT OF DISASTERS & CLIMATE CHANGE

IGAD Climate Prediction and Applications Centre (ICPAC)

Implemented by:

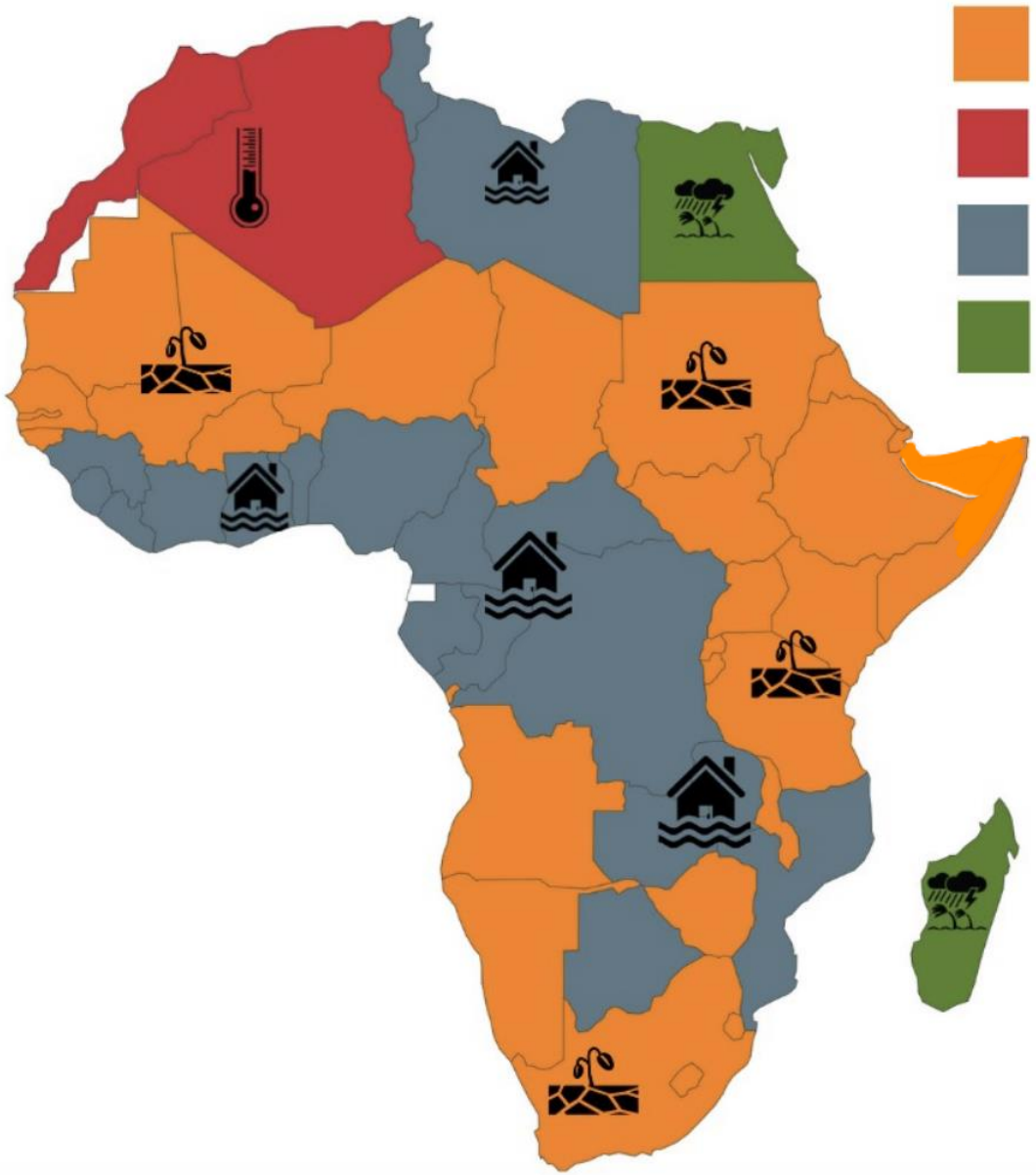
11/8/2025

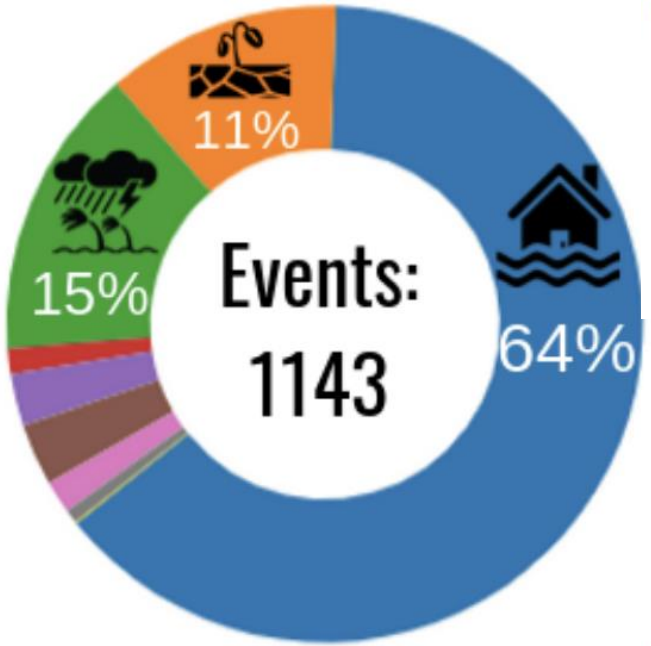
Africa's Temperature Anomalies, 1920-2020 (degrees Celsius)

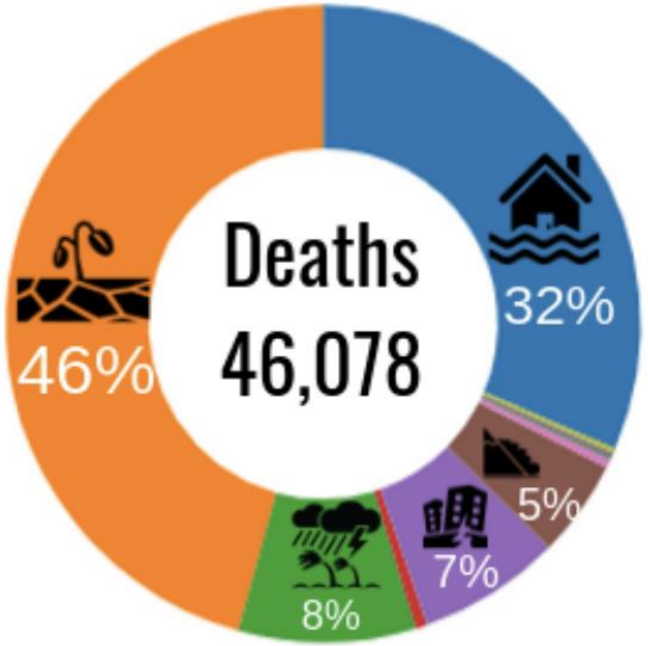


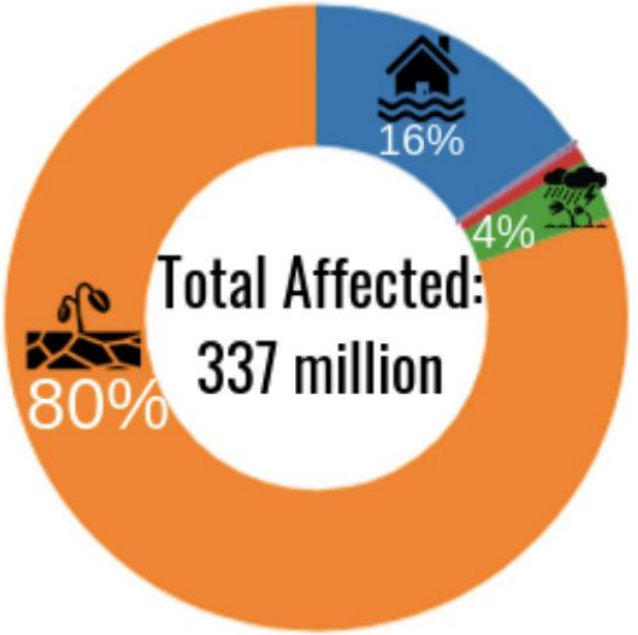
Source: NOAA 2021, World Bank

Disaster Type Affecting Highest Number of People by Country (2000-2019*)





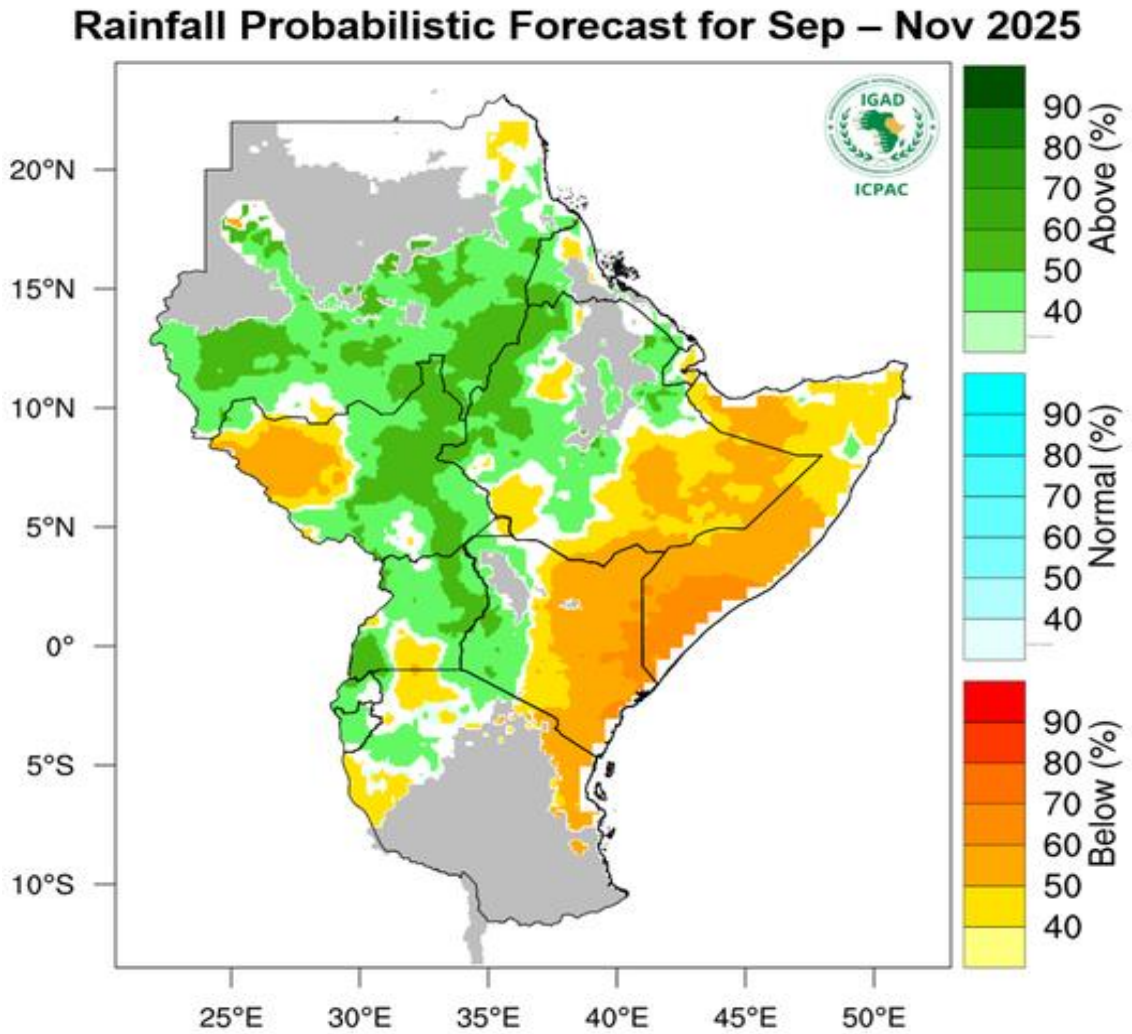


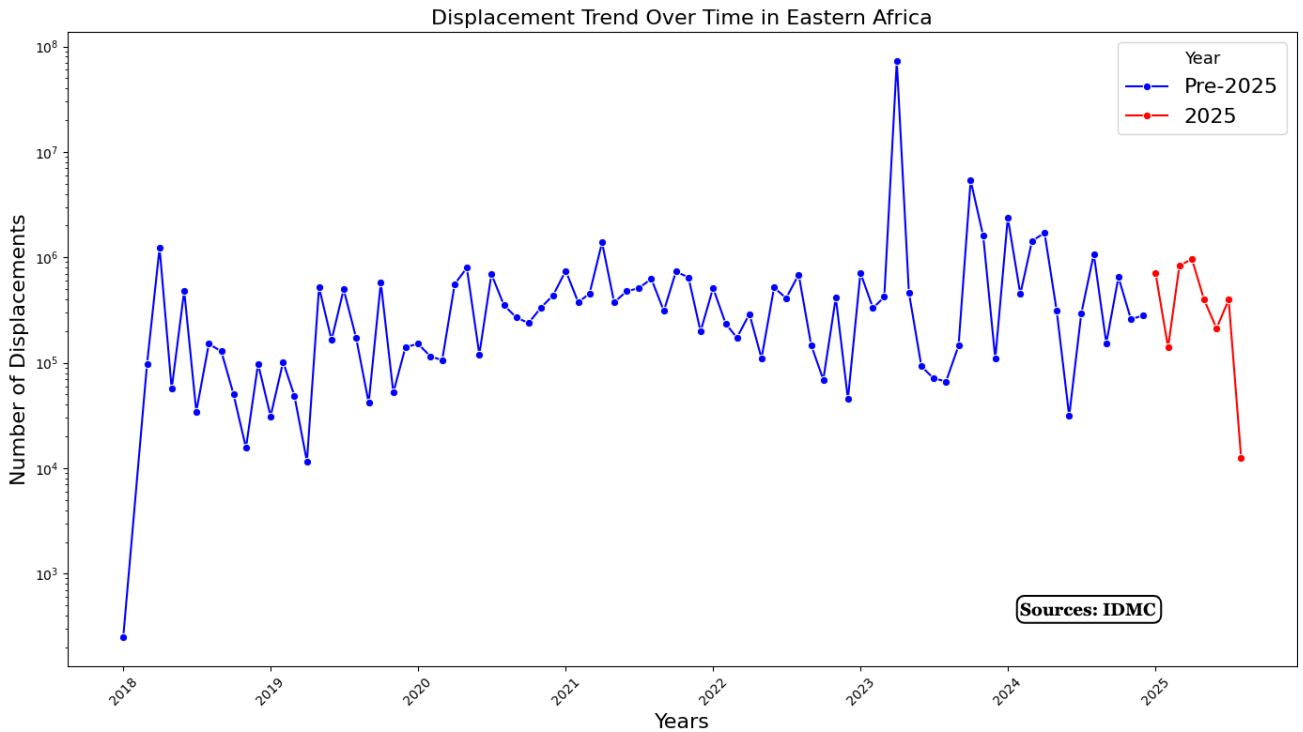


CRED/EM-DAT

CONTEXT AND RATIONALE

- IGAD is among Africa's most climate-vulnerable regions.
- 3.5 million people displaced in 2023 by droughts & floods.
- Climate, disasters, and conflicts coupled with weak governance constrain development, especially in borderlands.
- Frameworks exist (IGAD DRM, climate change, IGAD Migration policy, Free Movement Protocol, Kampala MECC, Transhumance Protocol…), but domestication & implementation remain limited.
- Disaster displacement remains a pressing reality that continues to disrupt lives and livelihoods, demanding urgent and coordinated action.


Rainfall Probabilistic Forecast for Sep – Nov 2025
IGAD
ICPAC
20°N
15°N
10°N
5°N
0°
5°S
10°S
25°E
30°E
35°E
40°E
45°E
50°E
90
80
70
60
50
40
Above (%)
Normal (%)
Below (%)


Displacement Trend Over Time in Eastern Africa
Number of Displacements
Years
Year
Pre-2025
2025
Sources: IDMC
2018
2019
2020
2021
2022
2023
2024
2025

MODIAC PROJECT : GOAL AND OBJECTIVES

Goal: to build resilience and support safe, dignified mobility across the IGAD region.

Objectives: To strengthen IGAD and Member States' capacity to anticipate, plan, and manage mobility linked to climate change and disasters

Core areas:

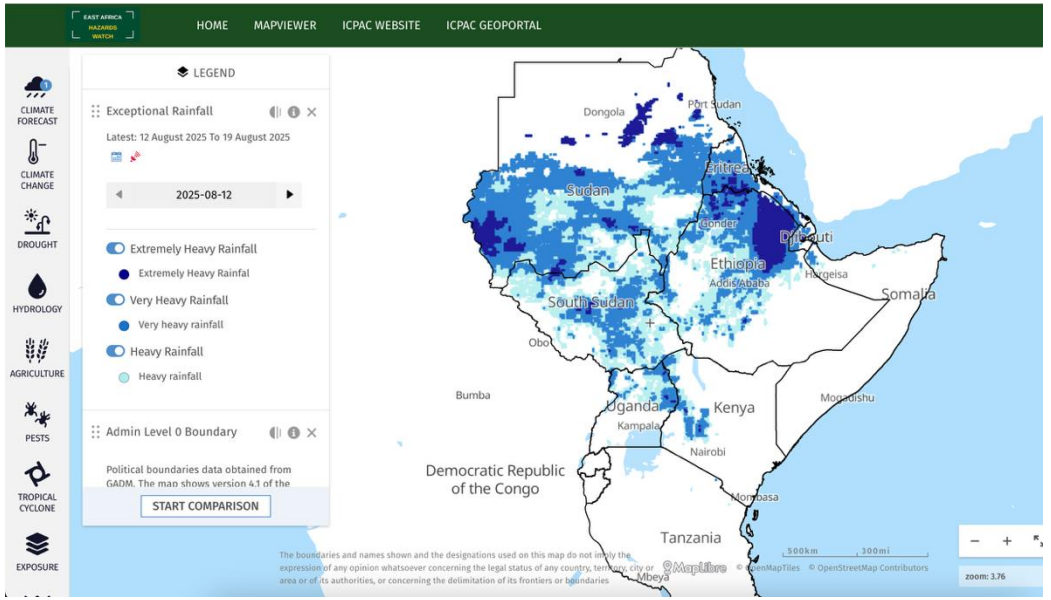
- Climate–mobility data modelling and forecasting (ICPAC)
- Integration into early warning and planning systems
- Policy harmonisation and cross-border dialogue fora
- Gender-responsive and community-based approaches

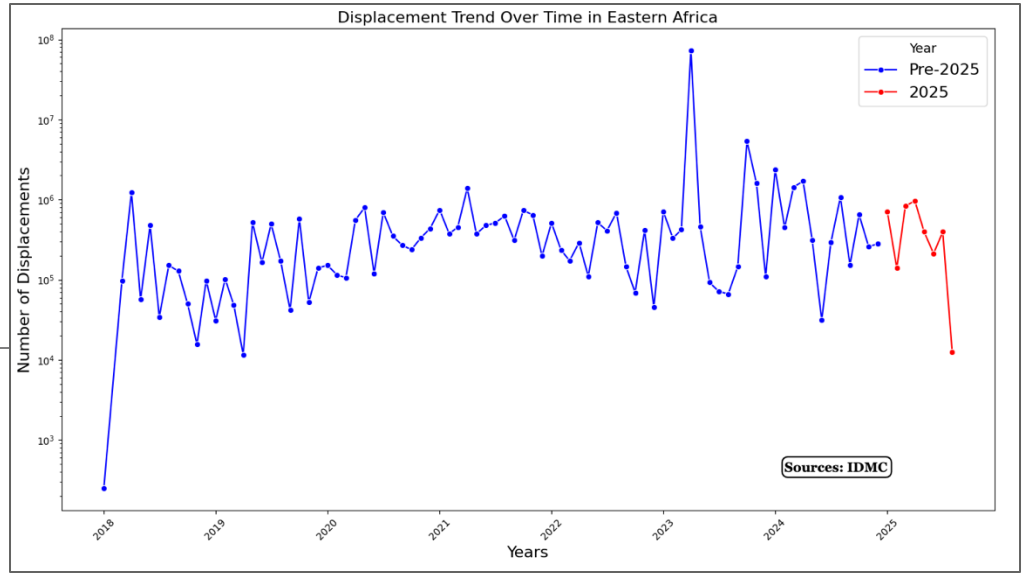
MODIAC OUTPUTS

- Output1-Strengthening IGAD‘s Technical Role
- Output 2-Enhancing ICPAC‘s Analytical Capacity
- Output3- Empowering Local Action in Border Areas

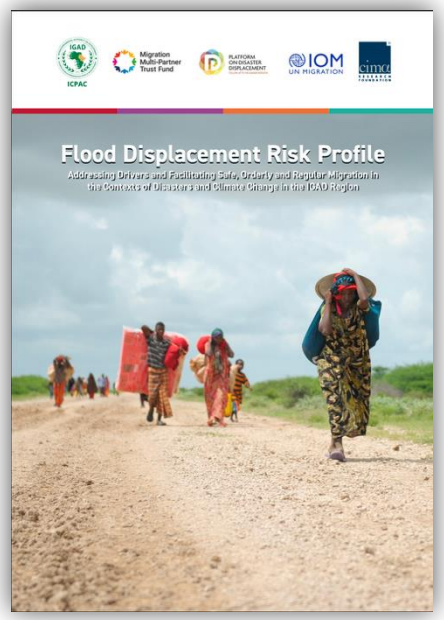
OUTPUT 2

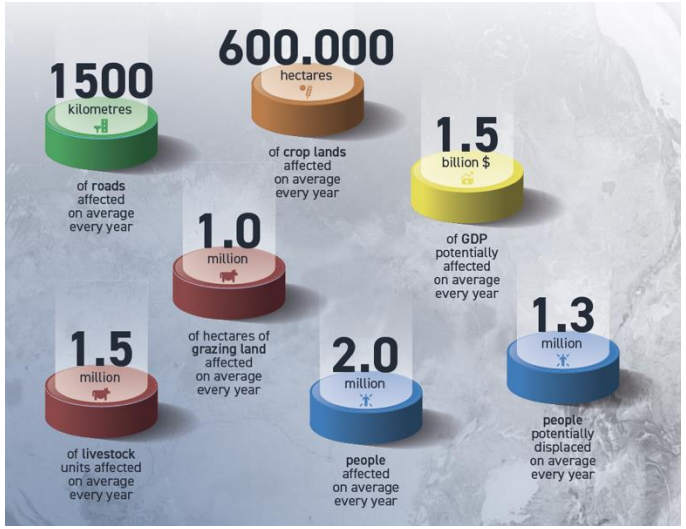
- **Early Warning Systems:** ICPAC develops displacement trend models (floods, droughts), integrates them into East African Hazards Watch, and improves displacement data governance.
- **Capacity & Communication**: Trainings for Member States and ICPAC, co-designed early warning bulletins, human mobility webpage, and engagement in regional/global knowledge platforms.
- **Preparedness:** Review and update preparedness plans at local level and design a regional model plan for cross-border climate mobility.

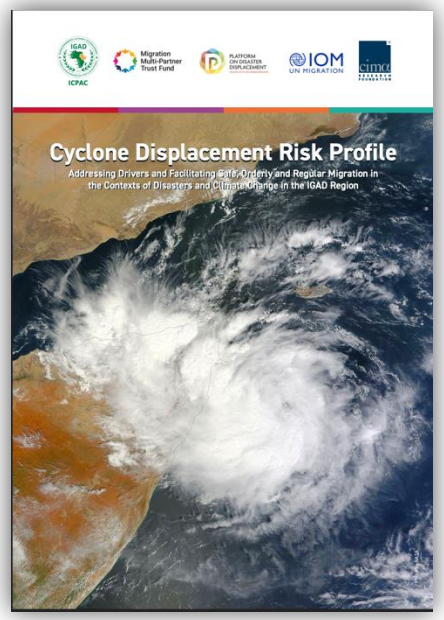




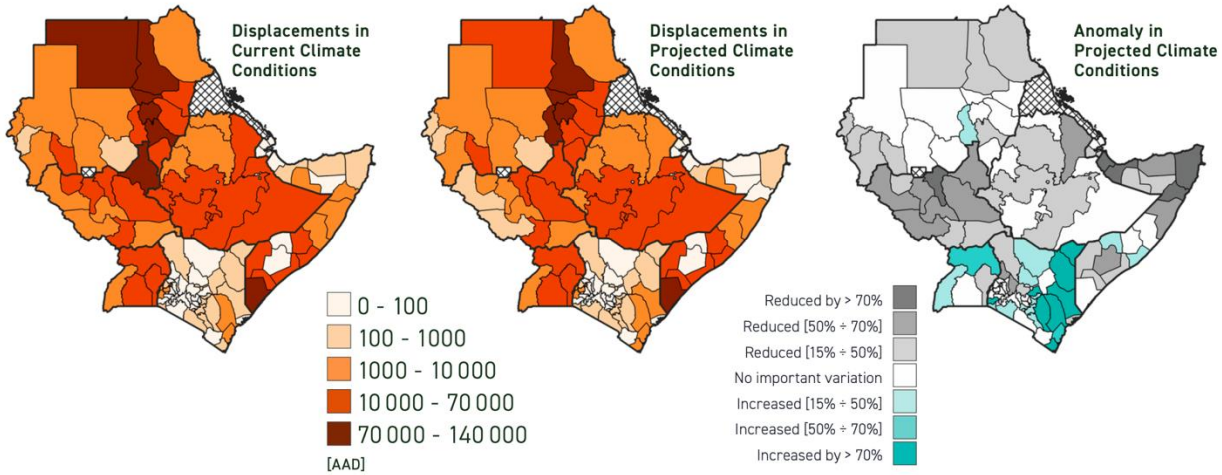
TWO DISPLACEMENT RISK PROFILES DEVELOPED



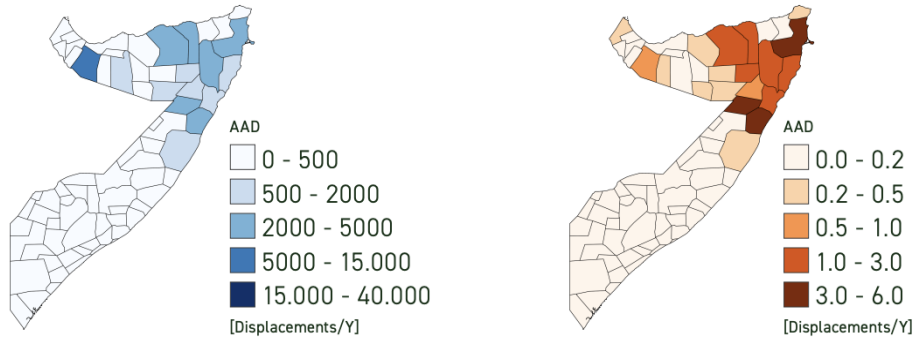




ANNUAL AVERAGE DISPLACEMENT TRIGGERED BY FLOOD EVENTS AT PROVINCE OR COUNTY LEVEL



ANNUAL AVERAGE NUMBER OF PEOPLE POTENTIALLY DISPLACED BY CYCLONE EVENTS AT DISTRICT LEVEL (ON THE LEFT) AND THE CORRESPONDING PERCENTAGE IN RESPECT TO THE TOTAL POPULATION AT DISTRICT LEVEL (ON THE RIGHT)



The maps above shows the annual average number of people potentially displaced due to cyclone events at district level: the total amount at country scale is around 30000, approximately 1/6 of the affected population. The northeastern part of the country is the one suffering the most.

MODELLING APPROACHES

- Short-term visualization: historic mobility & climate data.
- Long-term predictive analytics:
- - Machine learning for seasonal mobility.

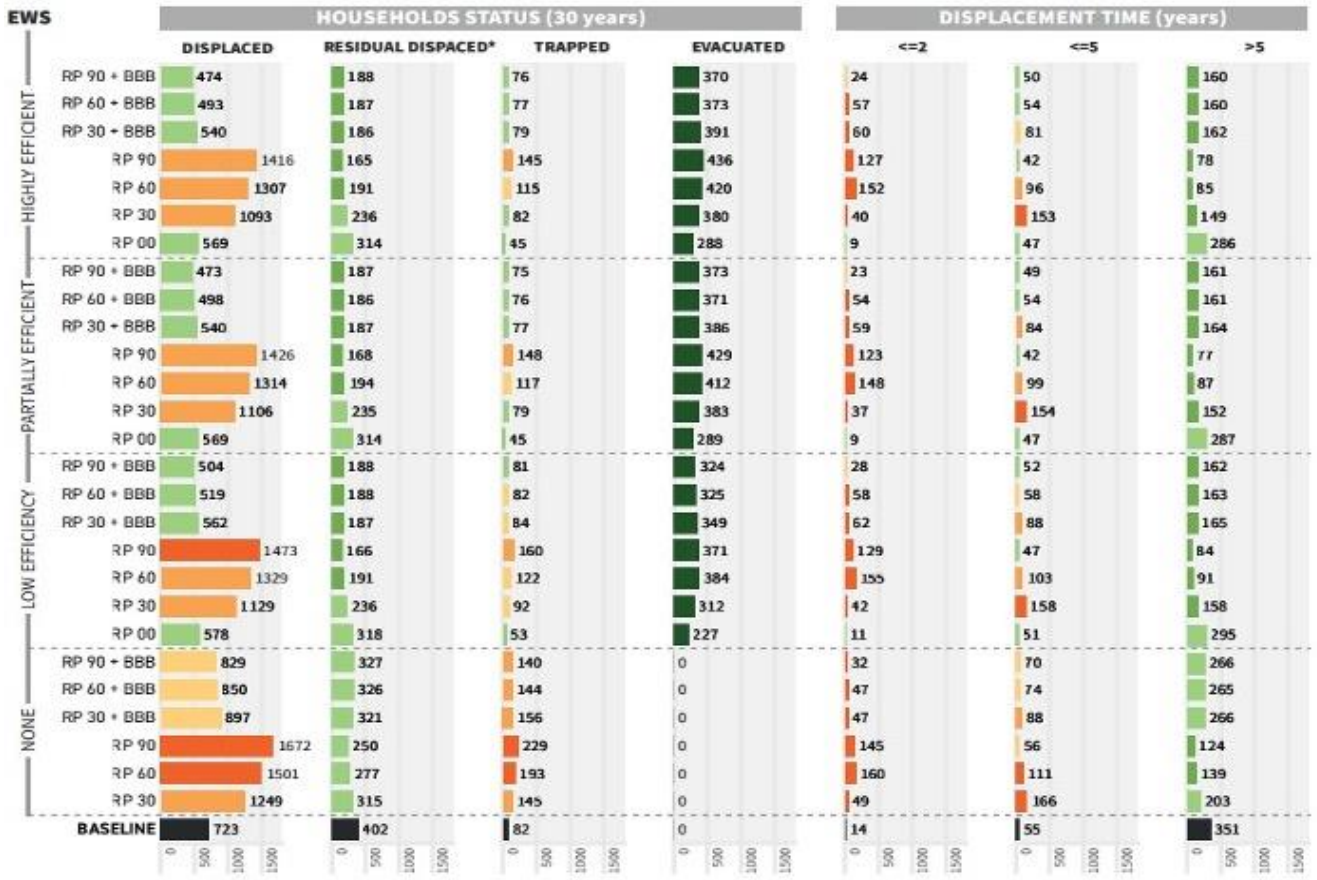
- Agent-Based Modelling (ABM).

- Hybrid ABM-ML Model

Combines Agent-Based Modeling (ABM) behavioral mechanisms with Machine Learning predictive strength

- Systems dynamics models.

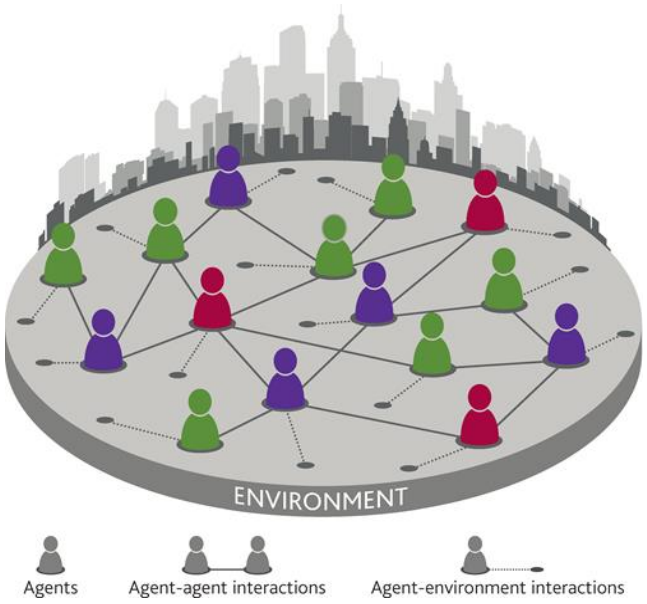
Results of ABM modelling-AN EXAMPLE



FLOOD DISPLACEMENT MODELLING

DECISION-MAKING MODEL - AGENT-BASED MODEL

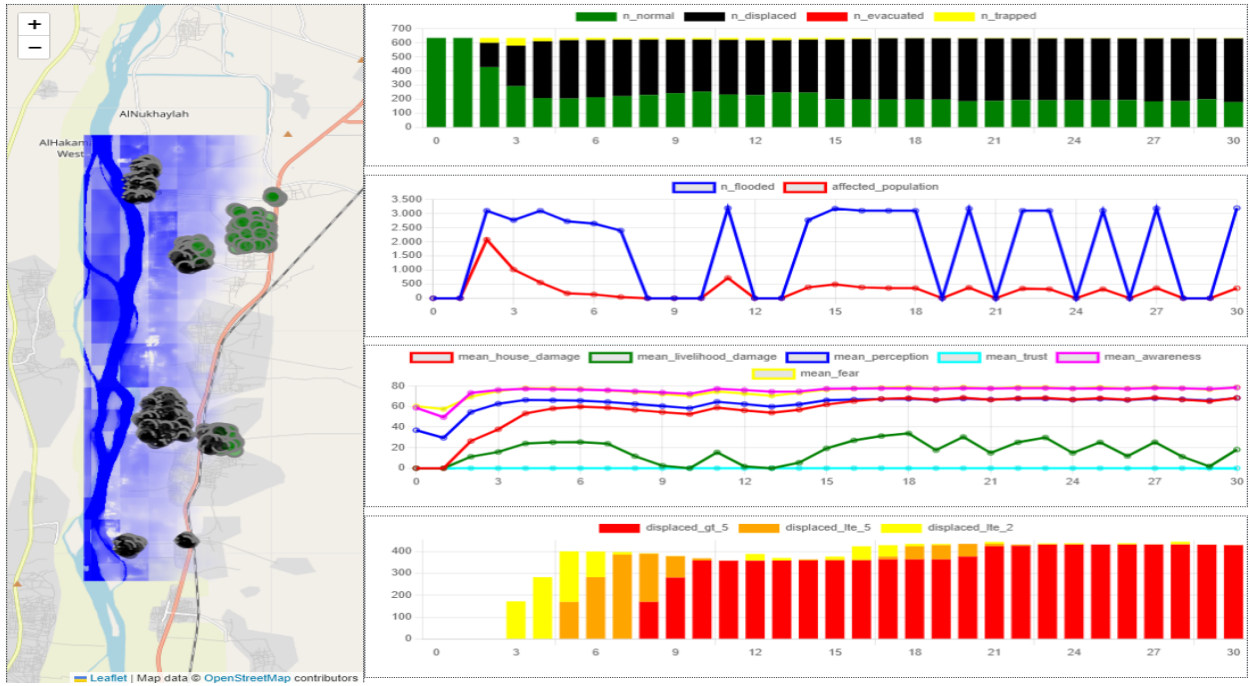
An ABM is "a computational method for simulating the actions and interactions of autonomous decision-making entities in a network or system, with the aim of assessing their effects on the system as a whole." (Dawson et al., 2011)



DECISION-MAKING MODEL - AGENT-BASED MODEL

- Model flood displacement using **systems perspective**
- Consider **dynamic** exposure and vulnerability
- Consider **local characteristics** and **cultural elements**
- Understand displacement **risk drivers**
- Provide displacement **policy analysis**
- **Support decision-making**

SCENARIO SIMULATION



Early Warning

False Alarm Rate

0 1

False Negative Rate

0 1

Initial authority Trust

0 1

House Repair Program

0 1

House Improve Program

Basic Income Program

Awareness Program

Events Parameters

Scenario

Medium Hazard

MAIN INSIGHTS FOR THE MODEL

EWS + Basic Income Programme BI is the best investment if the combination of more policies is not possible.

House Repair Programme reduces displacement duration, but it increases the n° of displaced HHs. HRP coupled with a Build Back Better Programme (BBB)to also reduce structural vulnerability.

Prioritize scalable plans, according to governments' resources.

Communities' needs and characteristics at the core for crafting strategic interventions.

Long-term effects have to be considered.

DROUGHT DISPLACEMENT MODELLING

GIZ HMCCC

- Objectives:
  - Determine the impacts of droughts on the livelihoods of pastoral and agro-pastoral communities;
  - Analyzing migration decisions in response to the effects of droughts;
  - Explore activities and policies that would increase the resilience to droughts.

- Findings:
  - Climate change impacts livelihoods
    - Declining animal health and livestock loss

There are norms that govern HMCCC
- Social norms
- Governmental regulations

HMCCC interacts with conflict dynamics
- Insecurity exacerbates the impacts of climate change
- Immobility
- Likelihood of conflict is increased

Gender
- Women participate in hazardous low return activity
- Men assume primary responsibility for decisions around migration

MODELLING APPROACH (1): MACHINE LEARNING AND REGRESSION ANALYSIS

- Utilise machine learning to explore the potential to develop a seasonal forecast of pastoralist displacement across international borders
- **Uses data detailing historic:**
    - **Environmental and climate events / change**
    - **Records of historic mobility patterns**
    - **Other data around influences on drivers of mobility – for example, conflict, disease, market prices**
    - **(also risk profiling of vulnerable households)**
- Aims to identify **relationships between climate, mobility and other influences**

INDICATOR / PROJECTION:

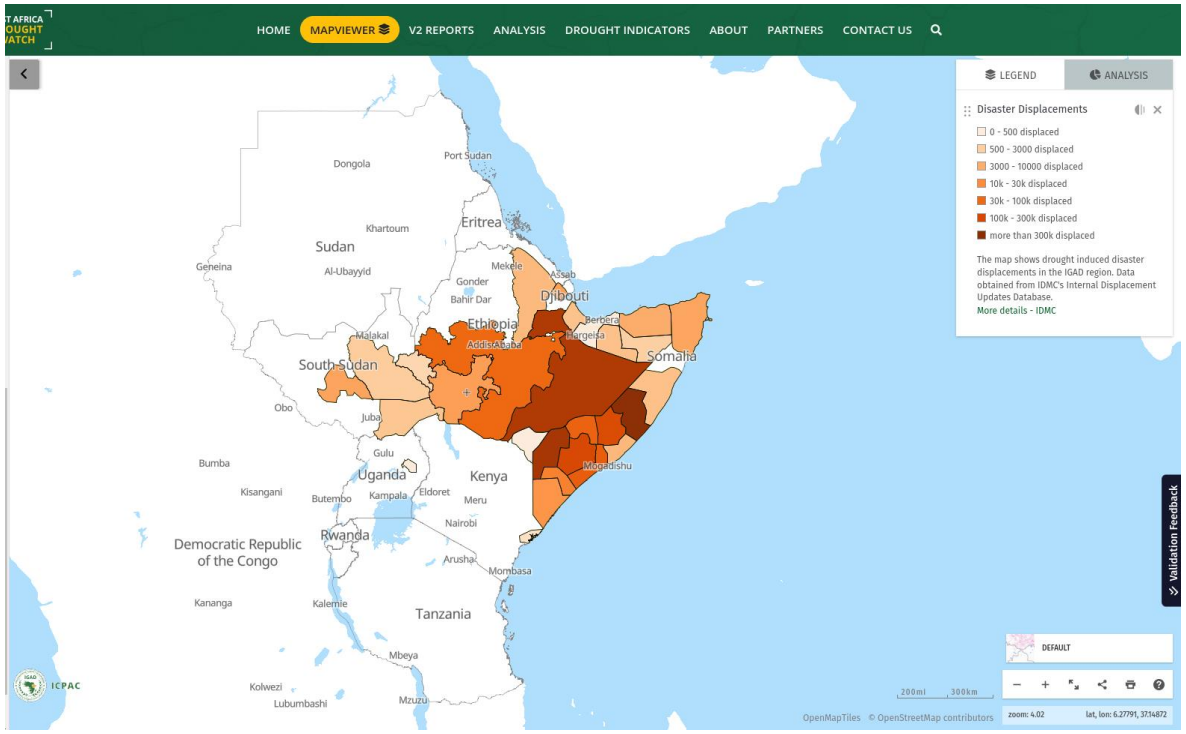
- Provide an indicator of the conditions under which we would expect to see waves of migration in the future

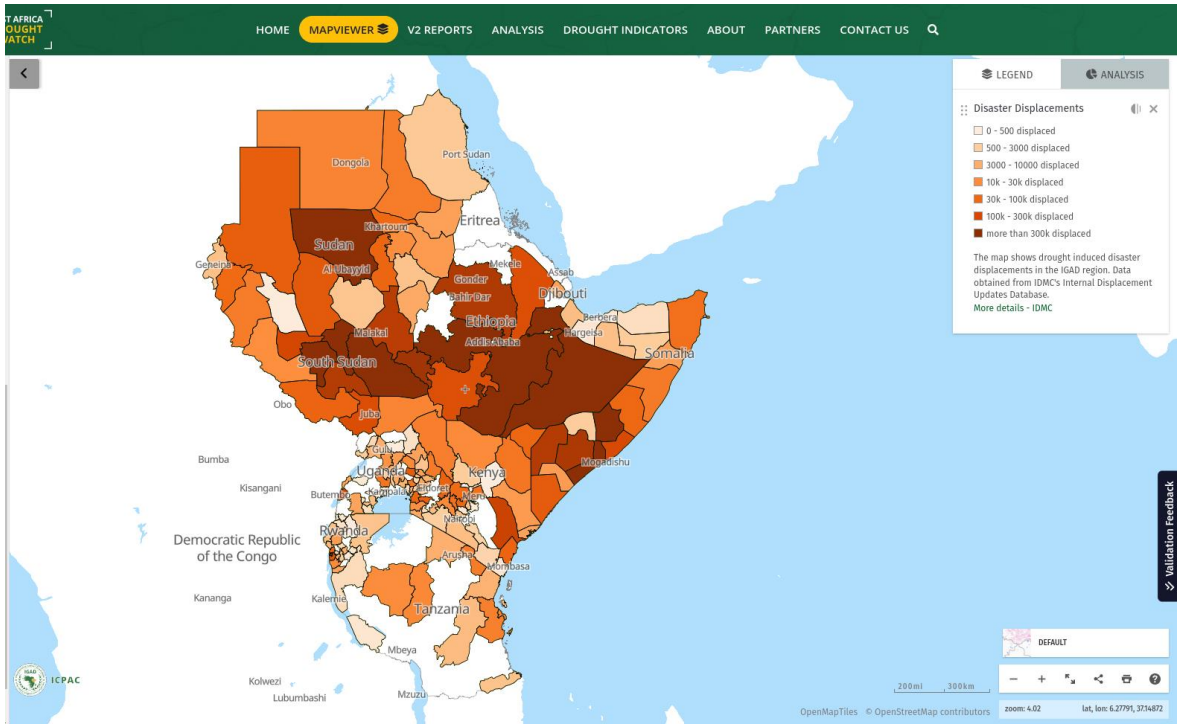
MODELLING APPROACH (2): IDMC SYSTEMS DYNAMIC MODEL

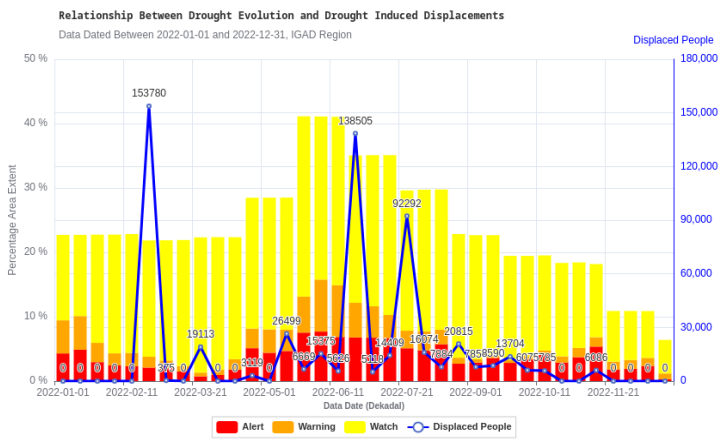
- Utilise existing IDMC systems dynamic model to understand policy options to reduce displacement pressure
  - **Uses data detailing historic:**
    - **Normalised Difference Vegetation Index (NDVI) data**
    - **Livestock population**
    - **Livestock prices**
    - **Displacement**
    - **Internally Displaced Population**
  - Aims to identify **relationships between pasture, livestock population, livelihood loss, displacement**
  - **SCENARIOS – under what conditions…**
    - Provides an opportunity to look at relationships between conditions associated with livelihood loss and displacement, and the potential policy interventions that can be made

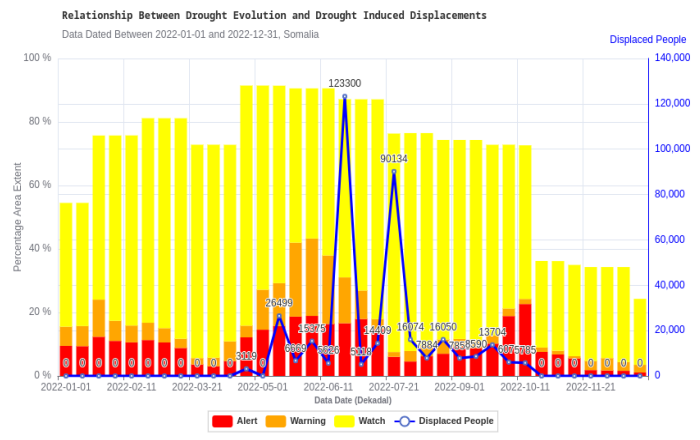
DATA COLLECTION AND SYSTEM INTEGRATION FOR OPERATIONAL USE

DISPLACEMENT DATA INTEGRATION WITH DROUGHT WATCH









HUMAN MOBILITY WATCH(DEMO)

System Architecture & Real-time Data Integration

IDMC Global Database

Purpose: Internal displacement figures

API: helix-tools-api.idmcdb.org

Data: IDP counts, events, analysis

Update: Daily

```
GET /external-api/gidd/displacement-data
?country=ETH&year=2024
```

IOM DTM

Purpose: Mobility & flow tracking

API: dtm.iom.int/api/v1

Data: Cross-border flows, sites

Update: Weekly/Monthly

```
GET /api/v1/flow-monitoring
?country=SOM
&type=cross_border
```

ICPAC Climate

Purpose: Climate triggers (CDI)

API: droughtwatch.icpac.net

Data: Drought indicators, forecasts

Update: Dekadal (10-day)

```
GET /api/drought-indicators/cdi?region=eastern_africa
&format=geojson
```

HDX Platform

Purpose: Humanitarian datasets

API: data.humdata.org/api/3

Data: Multi-source aggregation

Update: Variable by source

```
GET /3/action/package_search
?q=displacement+igad
```

System Capabilities & Impact

Real-time Monitoring

- Live displacement tracking across IGAD
- Climate trigger early warnings
- Cross-border movement flows
- Humanitarian needs assessment
- Mobile alerts to at-risk communities

Predictive Analytics

- 15-year displacement projections
- Climate hotspot identification
- Seasonal pattern recognition
- Early warning integration
- Risk scenario modeling

Decision Support

- Policy recommendation engine
- Resource allocation optimization
- Multi-stakeholder dashboards
- Impact assessment tools
- Intervention effectiveness tracking

Expected Impact

80%	4.3M	8	24/7
Displacement reduction potential	People protected by 2040	IGAD countries covered	Real-time monitoring

IGAD Member States

Djibouti, Ethiopia, Somalia, Sudan, Eritrea, Kenya, South Sudan, Uganda

Data Partners

- Internal Displacement Monitoring Centre
- IOM Displacement Tracking Matrix
- ICPAC Climate Prediction Centre
- OCHA Humanitarian Data Exchange
- World Bank Groundswell Project

Applications

- Humanitarian response planning
- Climate adaptation strategies
- Migration policy development
- Early warning systems
- Regional cooperation frameworks

Technical Stack

- React.js + Tailwind CSS
- Recharts visualization library
- RESTful API integration
- Real-time data processing
- Responsive design

IGAD Climate-Induced Human Mobility and Displacement Monitoring System | Last Updated: 10/28/2025 | Integrating IDMC, DTM, ICPAC & HDX APIs for comprehensive regional monitoring

East Africa Mobility Watch

Real-time monitoring of human mobility and displacement patterns in the context of climate change across the IGAD region

Export Report | Live Data Integration

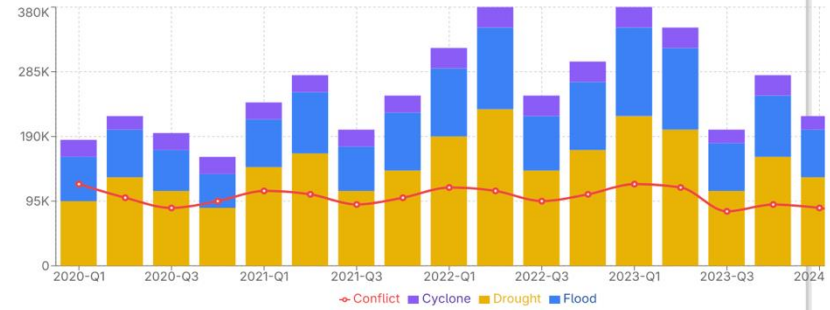
Country/Region: All IGAD Region | Time Period: 2020-2024 (5 Years) | Displacement Type: All Causes | Apply Filters

Total Displaced	New Movements	Climate-Induced	Returns
2.9M	890K	2.1M	450K
Internal displacement	2024 new cases	Drought & flood related	People returned home
↓ 11% from 2023	↑ 15% from 2023	75% of total	↑ 25% from 2023

Overview | Trends | Countries | Mobility | Projections

Detailed Trend Analysis

Displacement Causes by Quarter



Dry Season (Dec-Mar)	Long Rains (Apr-Jun)	Short Rains (Oct-Nov)
Peak Drought	Flood Risk	Recovery
Highest displacement from water scarcity	River flooding and displacement	Return movements increase

System Architecture & Real-time Da

IDMC Global Database
Purpose: Internal displacement figures

IOM
Purpose: Mobility & flow tracking
API: dtm.iom.int/api/v1

Purpose: Climate triggers (CDI)
API: droughtwatch.icpac.net

HDX Platform
Purpose: Humanitarian datasets
API: data.humdata.org/api/3

NEXT STEPS

- The need for early warning on risk of displacement due to drought, floods, landslides, conflict (later stage)…etc.
- Expand the evidence base on human mobility trends and risk of displacement in the IGAD region.
- Risk informed preparedness and contingency plans to better anticipate and manage mobility.
- Reaching last mile - (HUSIKA app) and strengthen local voices at global forums.
- Develop Human Mobility Watch as an interactive regional knowledge hub on mobility (with monitoring and forecasting capabilities) for early warning and decision-making support tool.

ICPAC

Thank You!

MoDiAC